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PROGRESS IN BROWN BOVERI DESIGN DURING 1934.

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INTRODUCTION.

ANOTHER year lies behind us, a year which brought no abatement of the severe and demoralising export crisis which holds in its grip the economic life of a great part of the world. During four years, the export industry of our country, including our own engineering branch, has felt the full weight of this crisis, which has spread gradually until it now encompasses, practically, every field of production. There is no denying that a certain spirit of hopelessness and resignation has begun to spread, and it is this which must be fought against, to-day, with an energy born of the conviction that a resolute will is the only arm by which our present troubles can be vanquished.

As regards our own particular position, we are happy to be able to report here, that, despite anxiety on account of the economic situation of our country, we have been true to our tradition of technical progress and can record encouraging headway, which is the fruit of much study and of investigation in many fields. The credit for the major part of this work is due to the creative and self-sacrificing spirit of our engineers and designing staff who have held true to their motto "ever forward".

The splendid example of this body of men should, indeed, be a lode star to all who tend to falter under present difficulties and the sacrifices which they entail and, particularly, to those who exhaust themselves in sterile criticism of certain aspects of the present crisis which are inevitable.

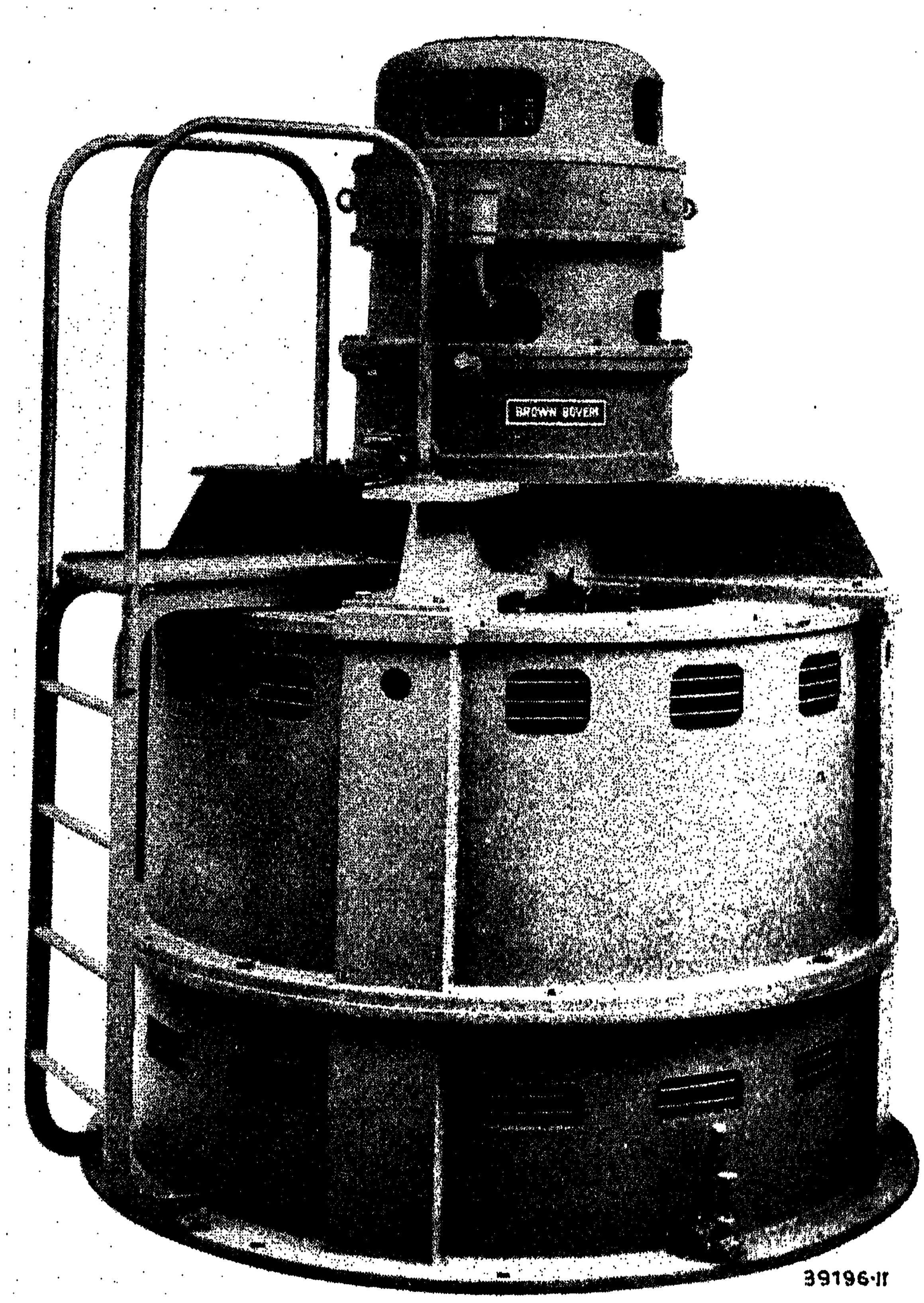
We conclude this short introduction with the expression of our firm conviction that the determination to succeed will bring us through the difficult times we are experiencing.

I. ELECTRICAL MACHINERY AND APPARATUS.

(1) *Synchronous machines.*

DEVELOPMENTS in the field of synchronous machines have given us the opportunity to devote considerable attention to modern welded designs. If, from an æsthetic point of view, the first results attained in this field were frankly displeasing, the example of modern welded design shown in Fig. 1 shows those graceful lines, which are the hall mark of all the constructional creations which we owe to *E. Hunziker*. Here, a word of appreciation is due to this eminent designer who retired in the course of 1934 to enjoy a well-earned rest after 43 years of creative endeavour in Brown Boveri service.

During the last 12 months, the synchronous motor found an increasing field of utilization which, we feel, is far from exhausted yet. When the ex-



pansion in the use of the standard squirrel-c is recalled, after the abolishment or, at least, of the regulations governing the connecting to supply systems, it is only logical to as: the synchronous motor, which provides its less current, will find wider application in s as are suitable to its starting characteri momentary current surge at falling into sy In any case, there is a tendency to exagg latter drawback as regards its effect on t system.

An order was booked by *Tecnomasio Brown Boveri* for two big 8-pole synchron advancers, 10,000 kVA and 7000 kVA re at p. f. = 0, over and under-excited. for the *Prenestina substation* of the *Itali Railways* and are to work on circuits o or 42 cycles, as desired. Starting up is of synchronous induction motors, which a of using the phase advancers as wattless-l erators.

Fig. 1. — Three-phase generator with built-on exciter, outp 220 V, 500 r. p. m., 50 cycles.

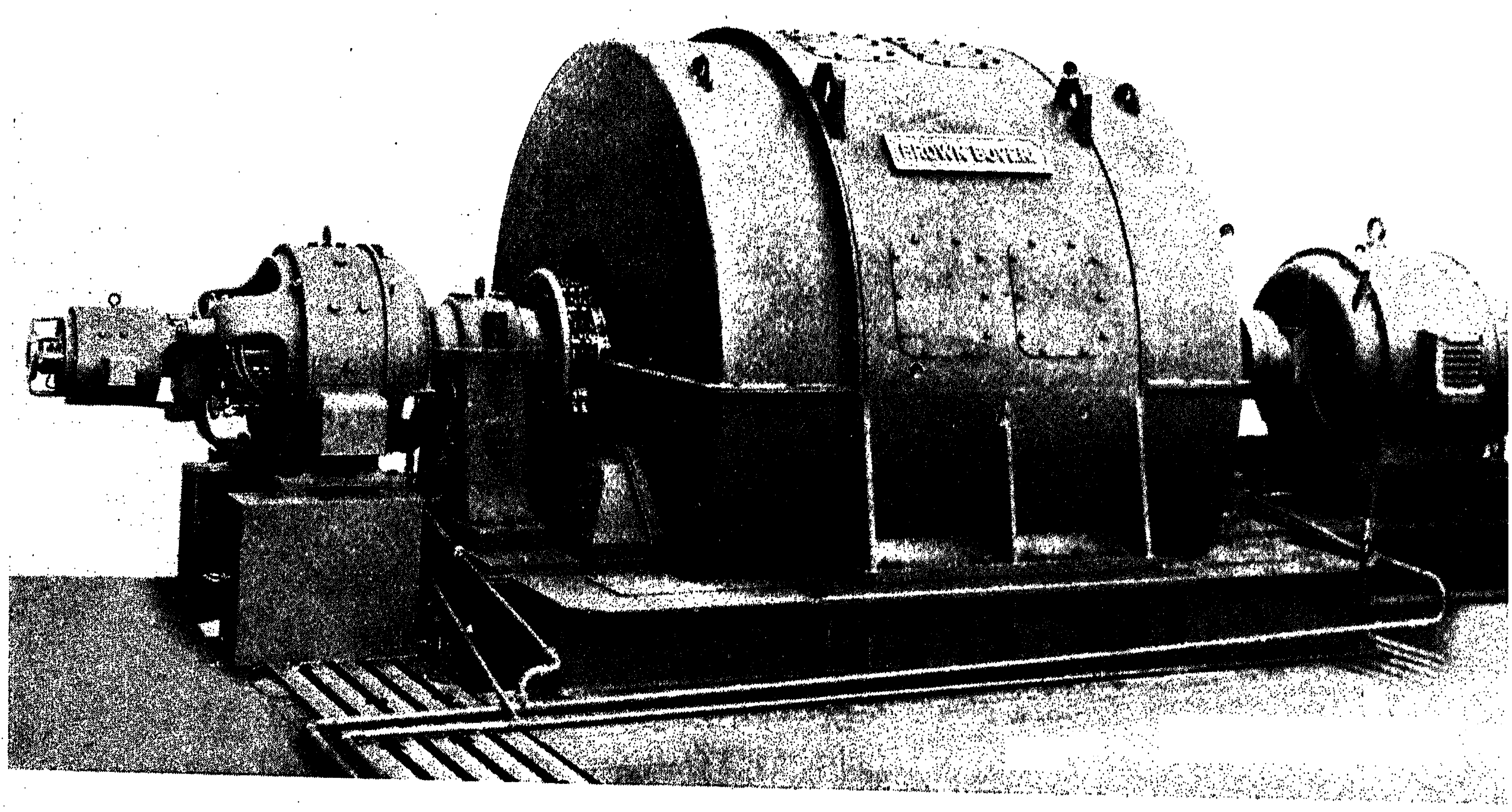


Fig. 2. — Three-phase synchronous phase-advancer with built-on main and auxiliary exciters, output 5500 kVA, 10,400/3000 V, p. 1000 r. p. m., 50 cycles. Starting motor with built-on exciter.

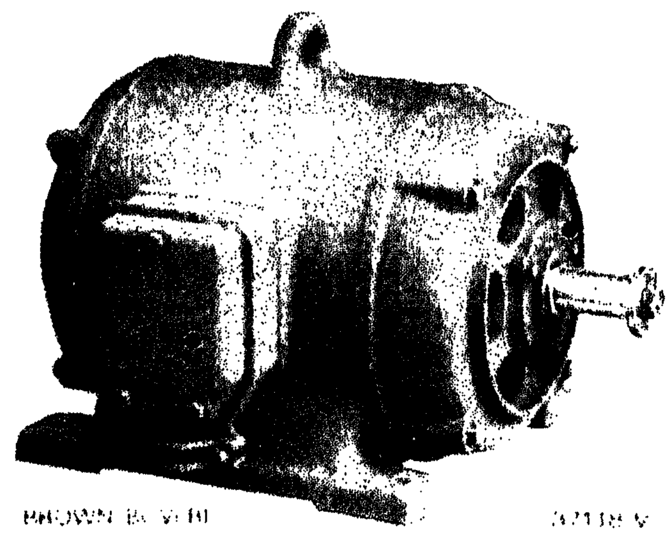


Fig. 3. Three-phase motor, Type MQe 44, drip-water proof design. Seen from terminal side.

(2) *Induction machines.*

General progress can be recorded in the development of our new lines of induction motors, mentioned here, last year. As was said, the line of completely-enclosed motors with external cooling was the first to be developed and it met with an encouraging welcome due to the high outputs attained which, especially in the small sizes, practically reach the outputs of the same sized motors of open design. In the last twelve months care was devoted to the completion of the development of motors of open design. Fig. 3 shows standard squirrel-cage motors of this series while Fig. 4 gives the vertical-shaft design. Fig. 5 shows a motor with feet on the housing, with centrifugal starter. Fig. 6 shows a type for flange mounting with slip-ring rotor. These motors are very compact, have great stability, are cooled axially and all have roller bearings, with grease lubrication.

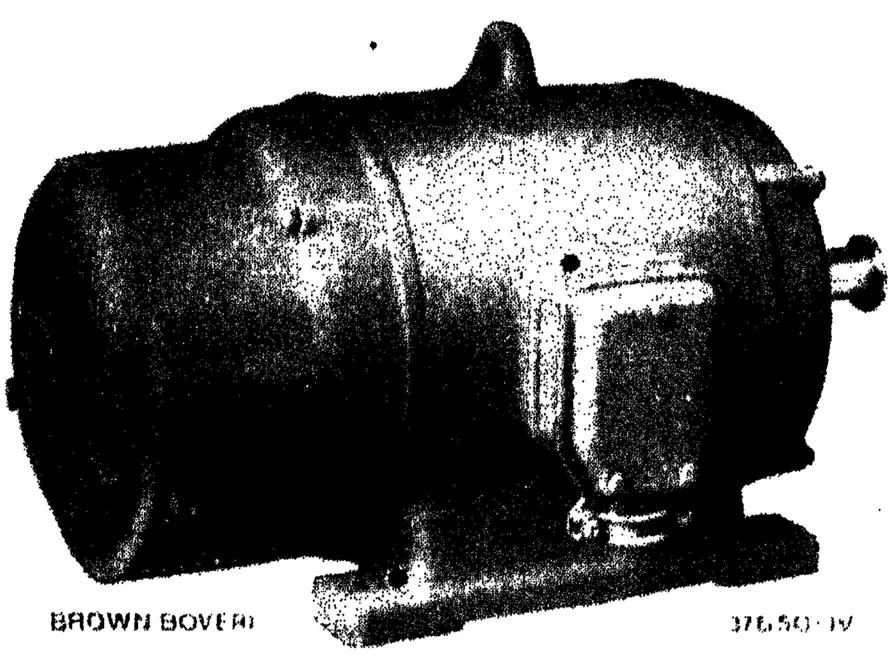


Fig. 5. Three-phase motor, Type MAe 64a, with centrifugal starter, 7·5 kW.

As to the line of enclosed motors with external cooling, as first-mentioned, the maximum output built to has been raised to 370 kW. Fig. 7 shows a motor with slip-ring rotor and continuously applied brushes for 300 kW at 970 r. p. m.

A remarkable novelty brought out this year is the *smallest type of single-phase motor,* Type KRg. It is for direct connecting to lighting circuits and shows a starting torque four times the rated one and this under a starting current of only a little over double the rated current (Fig. 8). This desirable result is due to a commutator all owing of starting up as a repulsion motor. During the starting period, a rim under the contact sectors is pressed outwards against spring pressure, owing to the greater centrifugal force, and it short-circuits the rotor winding. As the speed increases further, a centrifugal device comes into action and raises the brushes and the motor runs as a purely induction motor with squirrel cage rotor, at practically constant speed. This new small motor is built to six designs, namely:— with horizontal shaft, ball bearings and carrying foot; with ball bearing and supporting flange; for practically silent running with journal bearings and carrying foot; with journal bearing and supporting flange; finally as a vertical shaft motor with ball bearings and supporting flange and a free shaft end, either above or below. The motor is intended for refrigerators, small compressors, washing machines, ice machines, coffee mills as well as for household uses, the smaller

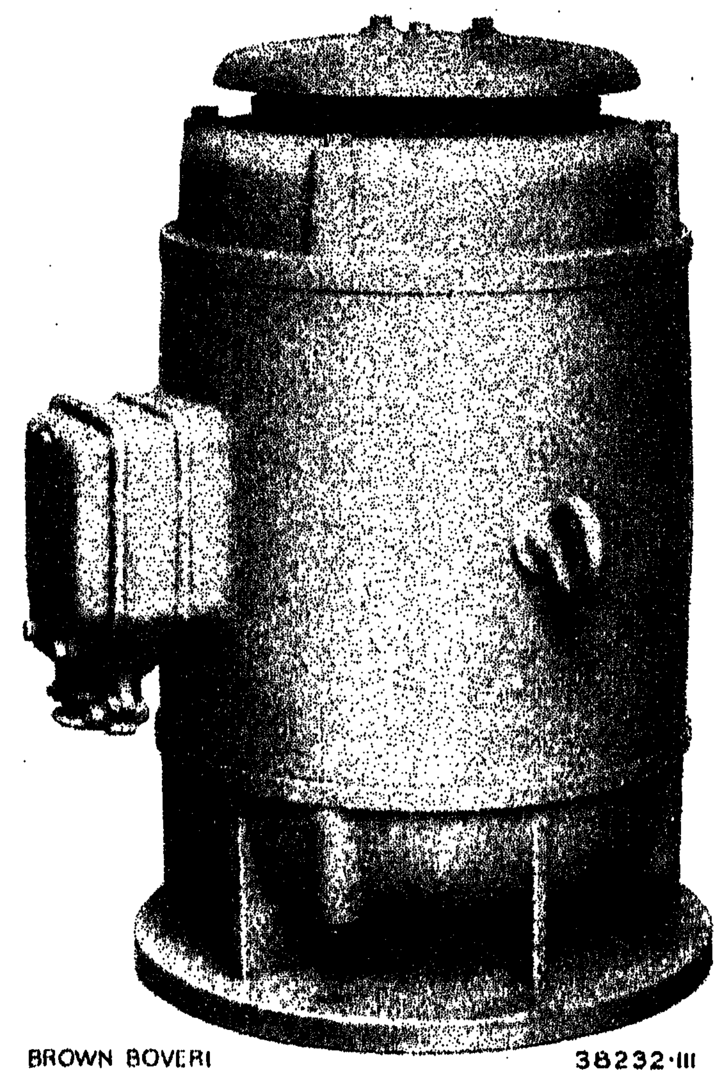


Fig. 4. — Three-phase flange motor with squirrel-cage rotor, with vertical shaft, drip-proof design, Type MQFVe 64 a, 7·5 kW.

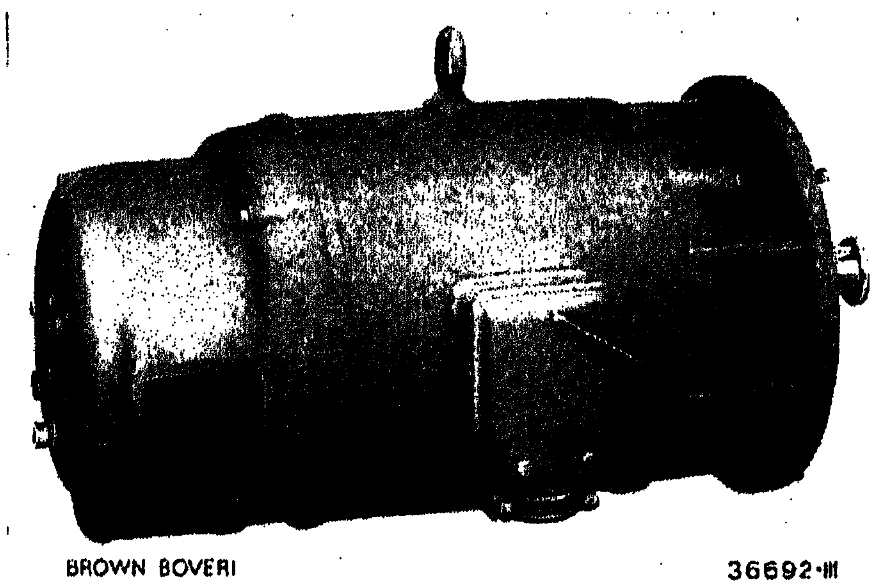


Fig. 6. — Three-phase motor with slip-ring rotor and flange, Type MSFe.

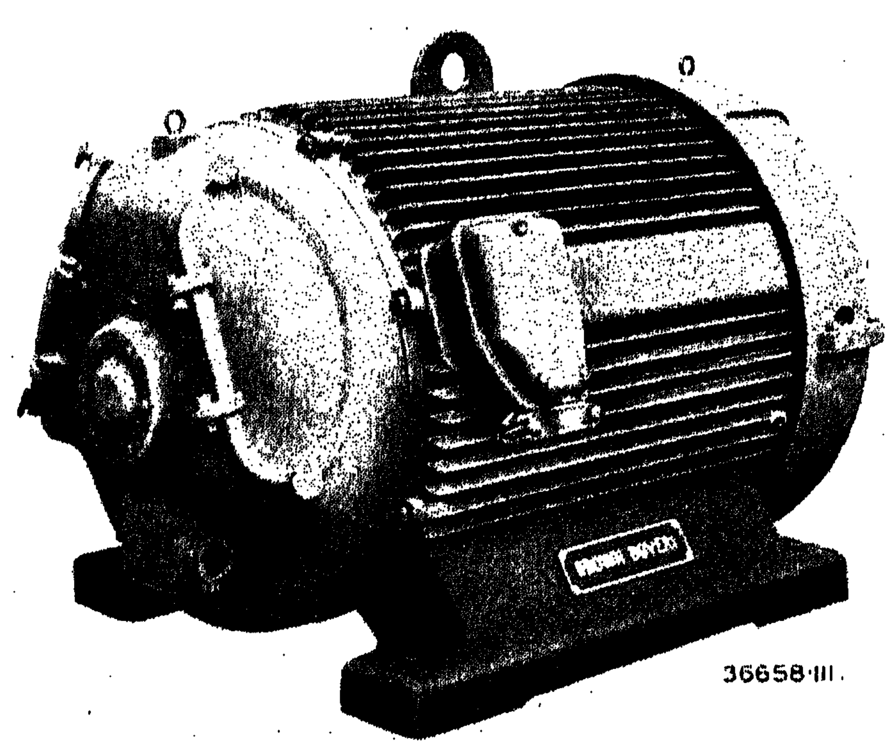


Fig. 7. — Three-phase motor, 300 kW, totally enclosed with external fan cooling.

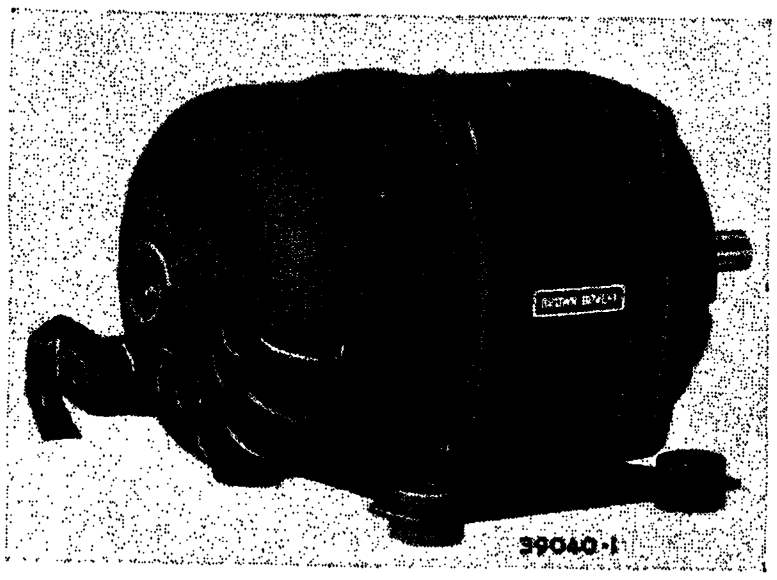


Fig. 8. — Single-phase motor with starting commutator for high starting torque at low starting current, 1/8 H. P., 110/220 V, 1425 r. p. m., 50 cycles, for running in both senses.

trades and electro-medicinal appliances. It is built for outputs of 1/8 up to 1/4 H. P. at 1425 r.p.m.

(3) *Direct-current machines.*

One of the most interesting developments in this field is the heavy-current machines of small output, in welded design. Mutators are ousting D. C. heavy-current dynamos from the position they held in the electro-chemical industry although, owing to particular conditions, in certain plants preference is still given to D. C. generators. Fig. 9 shows a D. C. generator for 6000 A, 80 V, 750 r.p.m. which with a second similar unit mounted on the same shaft will supply $2 \times 6000 = 12{,}000$ A. The set is driven by a steam turbine. Fig. 10 shows a new design of jacket-cooled D. C. motor, 33 kW, 750 r. p. m., 440 V and Fig. 15 a motor with speed regulation between 600 and 1200 r. p. m. to drive a sheet-metal rolling mill. It is built for 880 kW at 600 V and was delivered to the *L. von Roll'sche Iron Works, Gerlafingen* (Switzerland).

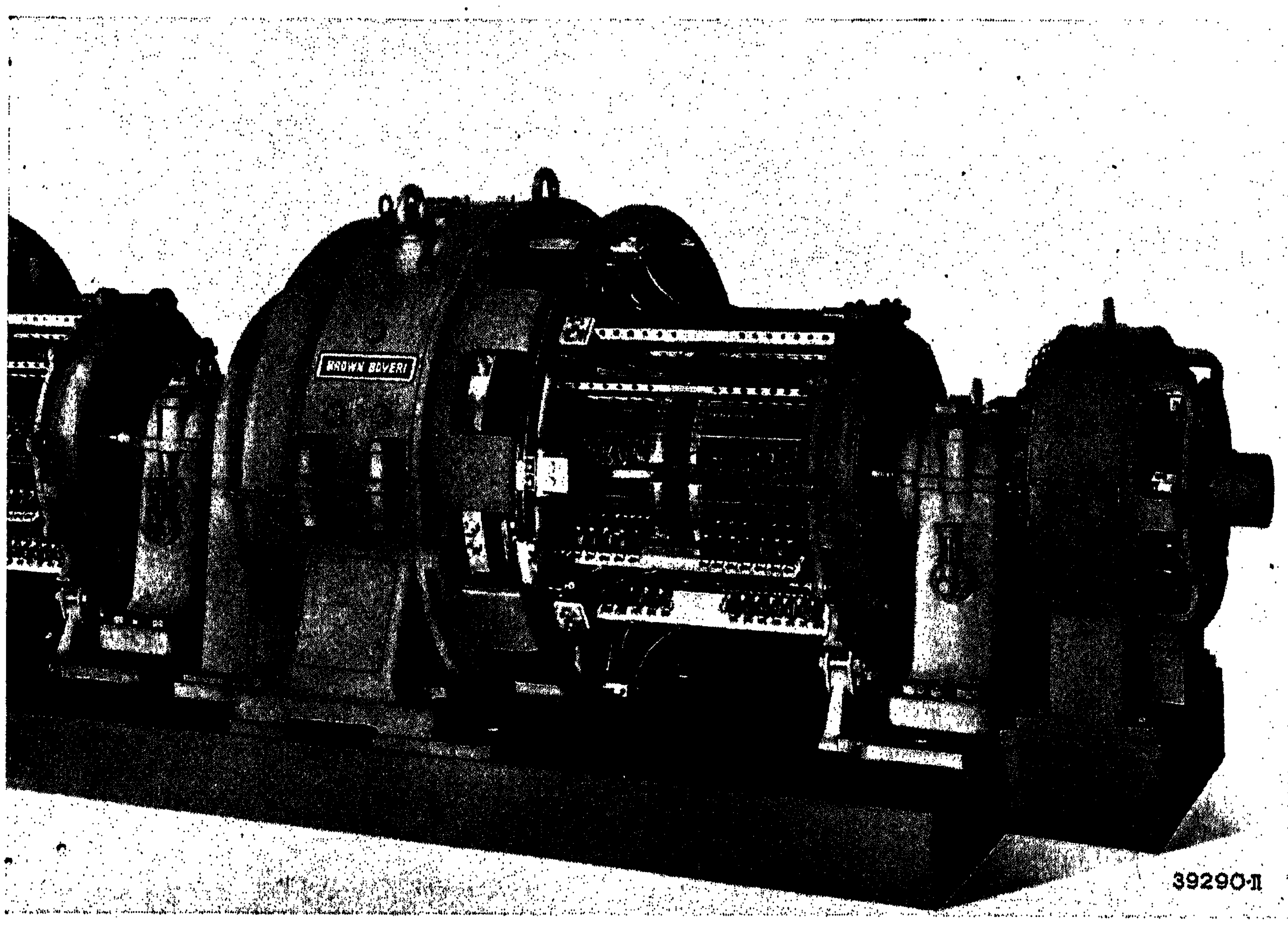


Fig. 9. — D. C. generator, 0—480 kW, 6000 A, 0—80 V, 750 r. p. m., with built-on exciter.

(4) *Motor drives.*

The *totally-enclosed externally-cooled motors,* mentioned in last year's report, have found their way into spinning-mill drives in the place of motors of open design. They are being increasingly used to drive a variety of appliances such as blowing-room machines, drawing frames, flyers and ring-spinning frames, because the air ducts of open motors get clogged up with fibre, etc. and demand considerable care. Thus, the higher initial cost of the enclosed motor is rapidly compensated for.

Enclosed motors are used successfully in dye works, bleaching and finishing shops, where they are very suitable on account of the damp, warm air of these shops which often contains corrosive vapours.

The *three-phase shunt commutator motor,* as well, has been introduced to dye-works and finishing shops and proved very suitable for the drive of stentering frames, calenders, cloth-printing machines. This type of motor allows of speed regulation within a 1 to 10 range and even beyond and this when driv-

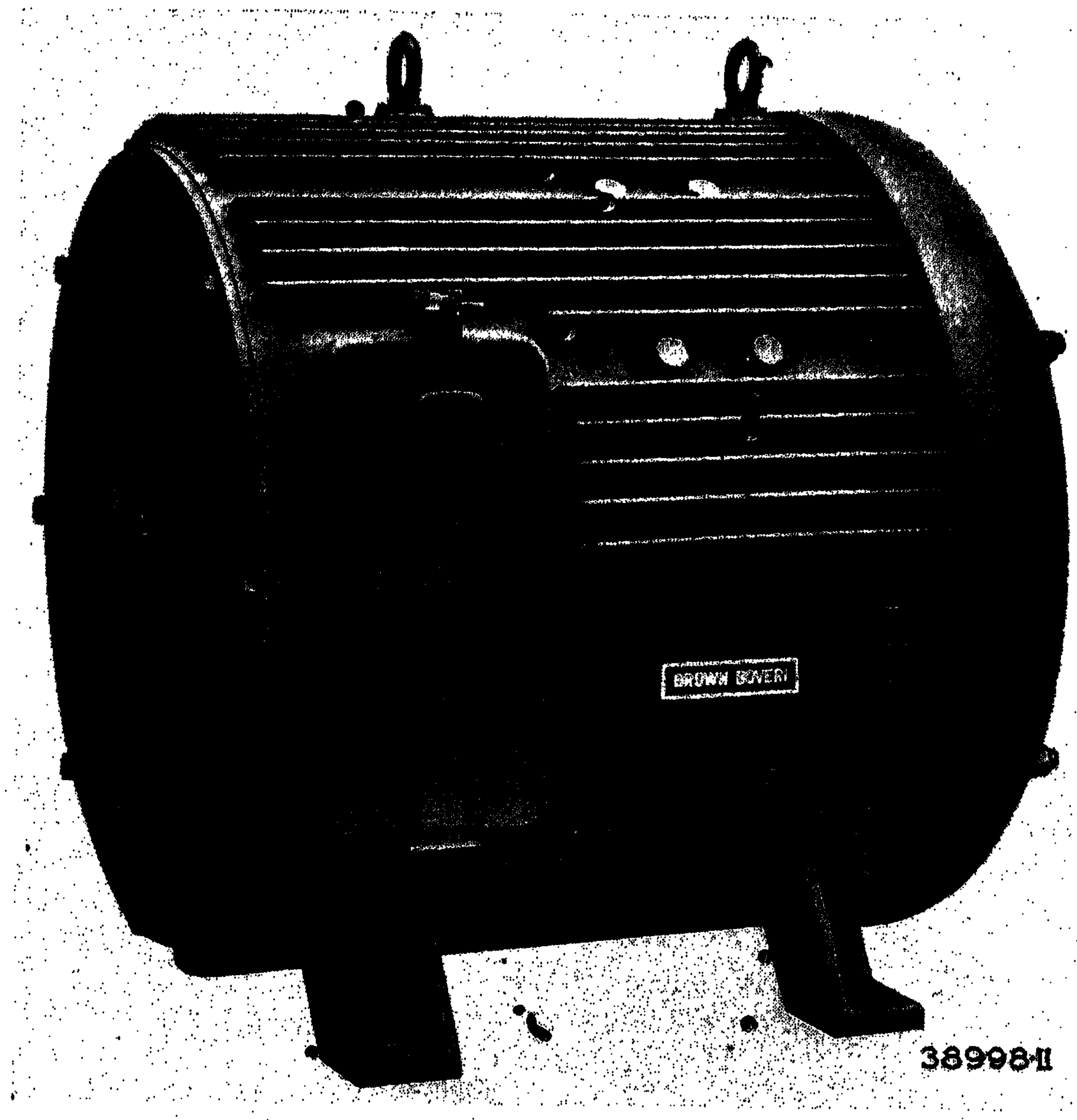


Fig. 10. — D. C. motor, 33 kW, 440 V, 750 r. p. m., design with 2 journal bearings.

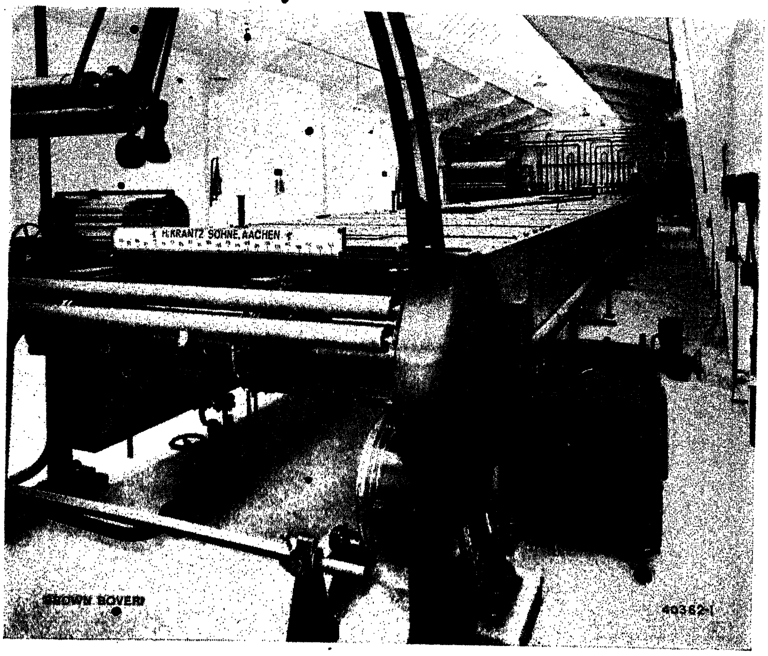


Fig. 11. — Variable-speed main drive of a stentering frame with shunt commutator motor 7·5 kW, 1600—320 r. p. m., with auxiliary motor for remote control; 12 auxiliary drives with squirrel-cage motors for fans and width adjustment.

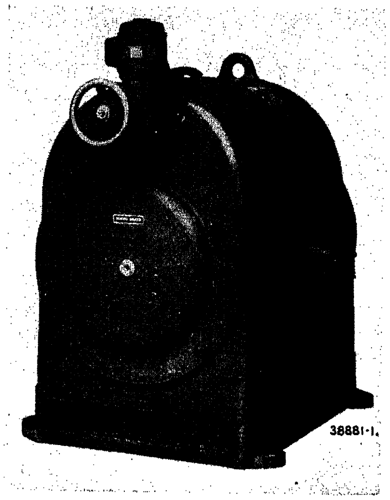


Fig. 12. — Three-phase shunt commutator motor, 13 kW, 500 V, 50 cycles, speed variable between 470—1400 r. p. m., with electrical remote control of the brush rocker by means of a small induction motor.

ing a single machine as well as for multiple motor drive of a set of machines. Fig. 11 shows the main drive of a stentering frame the speed of which can be regulated by brush displacement over a 1 to 5 range. The motor can be started, regulated and stopped from two push-button control posts. To this end, a small auxiliary motor is mounted on the main motor, to displace the brushes of the latter. There are also other "Out" push-buttons available on stentering frames. At each new switching-in impulse, imparted by depressing the "In" push button, the motor automatically adjusts itself to that working speed it was running at before. The stentering frame has also got 12 additional small squirrel-cage motors to drive fans, as well as a reversible motor, for width adjustment, controlled by the aforesaid push-button control posts. The brush-regulating motor is seen clearly in the illustrations of motors given in Figs. 12 and 13.

Three-phase, shunt commutator motors are also used by us for the drive of the charging blowers of Velox steam generators. In this case, the pressure of the steam automatically regulates the speed of the motor and, with it, the output of the steam generator, so that the said steam pressure remains constant.

The simplicity with which the speed of three-phase commutator motors can be regulated without losses makes them very suitable to drives in the paper-making industry as well as in rubber calender drives, the drives of various machine tools and those of the cement industry.

The machine-tool motors, mentioned in last year's report, have already found a variety of practical applications. This is especially the case

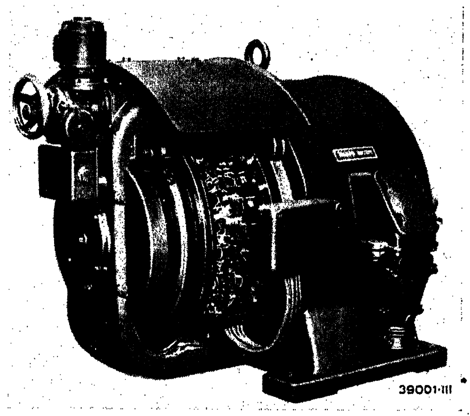


Fig. 13. — Three-phase shunt commutator motor, 36/8·3 kW, 1120/260 r. p. m., 380 V, 50 cycles.

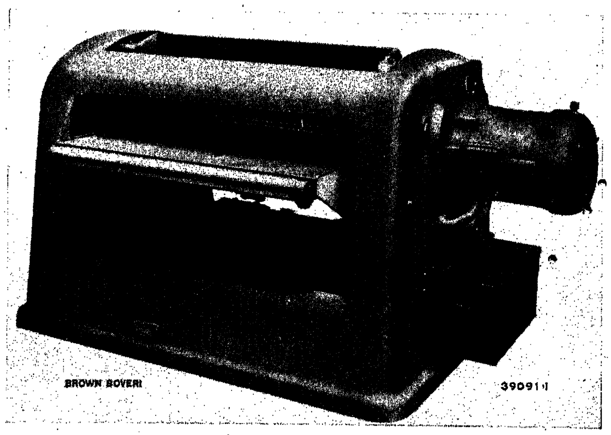


Fig. 14. — Smoothing planer driven by built-on motor, 11 kW, control by push buttons and automatic star/delta switch.

for them in the drive of wood-working machinery, as built-on motors. Fig. 14 shows a smoothing planer with its built-on motor of 11 kW at 3000 r. p. m.

A very welcome improvement has been devised for the regulating apparatus of the *sectional drive of paper-making machines*. It is essential, here, that the speed set to should be maintained with great precision. Now, in our regulating system, the master frequency is a direct measure of the working speed. We have developed a new regulator which is directly influenced by this master frequency and which works to a precision of $+ 0{\cdot}25\,\%$. It is, by far, the most precise regulator created up till now for the purpose it has to fulfil.

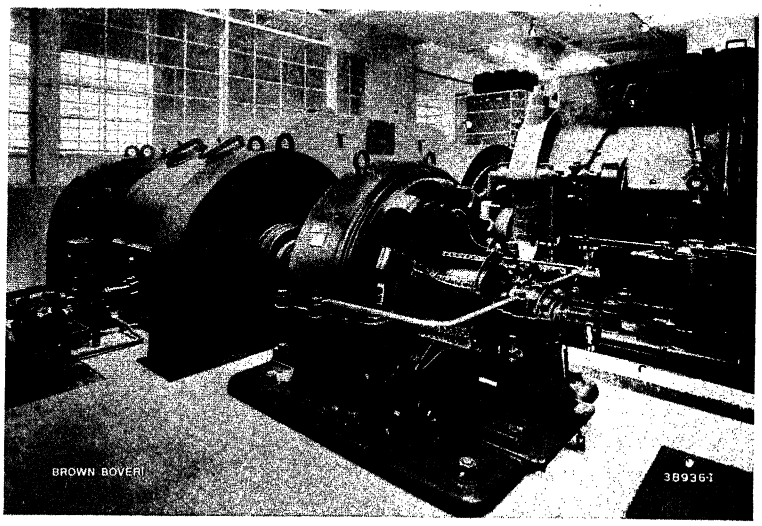


Fig. 15. — D. C. motor Type G 990/6/350, 900 kW, 600—1200 r. p. m., 600 V, to drive a blooming mill.

The electric equipments we delivered to the *L. v. Roll'sche Iron Works, Gerlafingen* (Switzer-

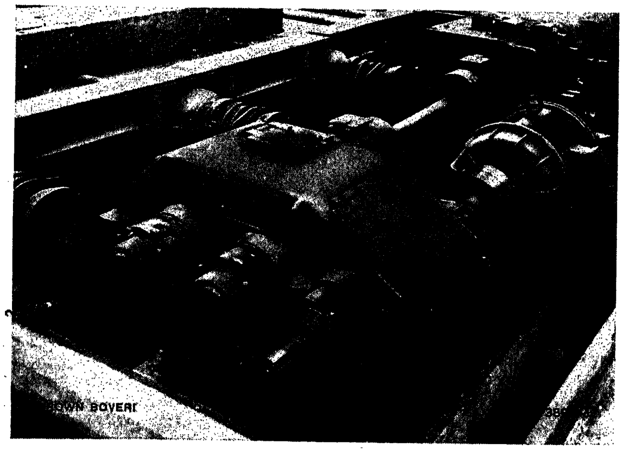


Fig. 16. — Group drive of the rollers of a tilting table belonging to a blooming mill by a three-phase motor, totally enclosed, 38·5 kW, 600 r. p. m., 500 volts, 50 cycles. On the left, are seen separate rollers of Sack design with totally enclosed 3-phase motors, 5 mkg, 50 V, 180 r. p. m., 14 cycles.

land) for a new roughing mill were put into service last spring with signal success. We would only mention here two of the numerous drives delivered:— Fig. 15 shows the drive of the blooming mill by a D. C. compound, 900 kW, 600 V motor to carry sudden 100 % overloads and to give speed regulation in the range of 600 to 1200 r. p. m. This motor drives the pinion gear of the mill by means of a reduction gear and a Babba-Klus coupling. There are two fly-wheels on the pinion shaft to absorb load peaks. The two 1200-kW mutators for the supply of the two rolling-mill motors can be seen in the background. Fig. 16 shows a part of the roller drive of the blooming mill. On the left is the feed-roller track, which is of Sack design, each roller being direct driven by its own enclosed motor developing a torque of 5 mkg, at 50 V, 180 r. p. m., 14 cycles (see last year's report). On the right, there is a 38·5-kW three-phase motor for 40 % switching-in time and built for 600 r. p. m., 500 V, 50 cycles. It drives the different rollers of the tilting table through a common spur-wheel gear and individual conical gears.

A more detailed description of this interesting plant will be published in a latter number of the Review.

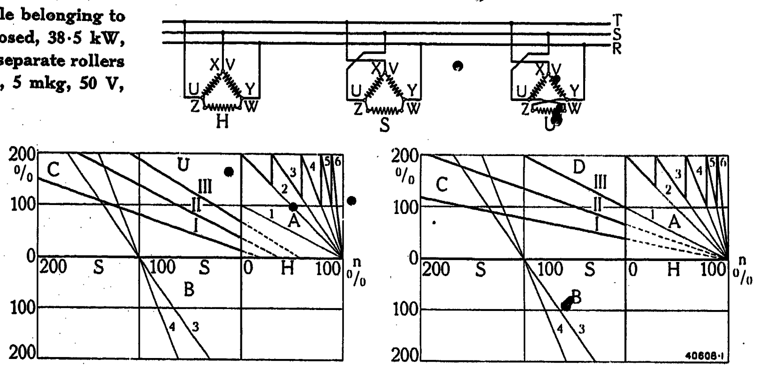


Fig. 17. — Power and braking curves with the new Brown Boveri sub-synchronous braking connection with reversed phase (left), as well as power and braking curves with standard control and counter-current braking (right).

Ordinates: motor torque in %.

B. Power lowering.
C. Super-synchronous brake lowering.
D. Counter-current lowering braking.
H. Hoisting.
S. Lowering.
U. Braking with reversed phase.

In our last year's report, mention was made of a new *simple braking connection for hoisting gears* with standard three-phase induction motors. Since then, we have equipped a number of hoisting appliances with this device, up to an output of 180 kW and with most satisfactory results.

In lowering braking with counter-current lowering braking connection, two phases of the induction motor are interchanged causing the motor to generate a counter-torque to that exercized by the load. In the

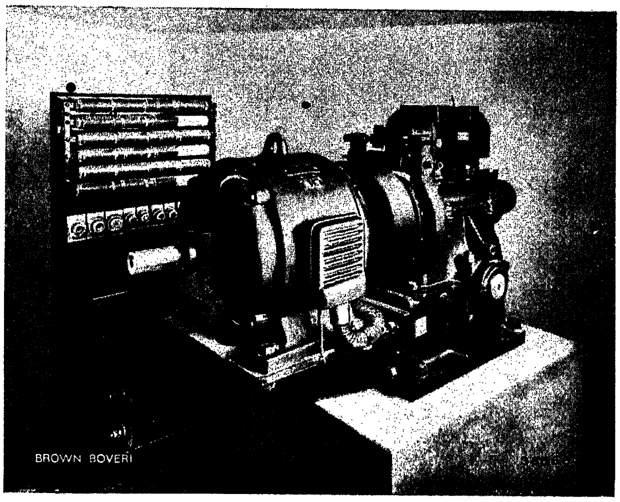


Fig. 18. — Motor for a lift built together with a lift hoist.

new connection only one phase is rotated through 180°, as shown in principle in Fig. 17. This gives a much better speed-torque curve in the lowering braking range so that, with relatively simple means, it is possible to attain speed regulation with standard induction motors when used on hoisting devices and similar drives. The difference between the standard counter current lowering braking connection and the new Brown Boveri braking control with reversed phase is clearly illustrated by the speed-torque curves of Fig. 17.

Two years ago, we mentioned our motors for *practically noiseless running*. These have met every requirement made of them and been used in increasing number in goods and passenger-lift drives, in their squirrel-cage design, on account of its simplicity and rugged character (Fig. 18).

Fig. 19 shows a *hoisting controller* of our well known design, with separate switching elements and individual blow-out. This controller has a new drive from below which allows of simple and easy regulation of the motor. Drum-type controllers can only be used for light duty of not more than 200 switching per hour and must be overhauled nearly every week. Controllers with separate switching elements, however, can be used for outputs up to 190 kW and for 600 switchings per hour and, even under these severe conditions, can work without a break for 6 months without overhauling and until it becomes necessary to change the contact blocks. The savings effected soon cover the higher cost of purchase of the latter apparatus.

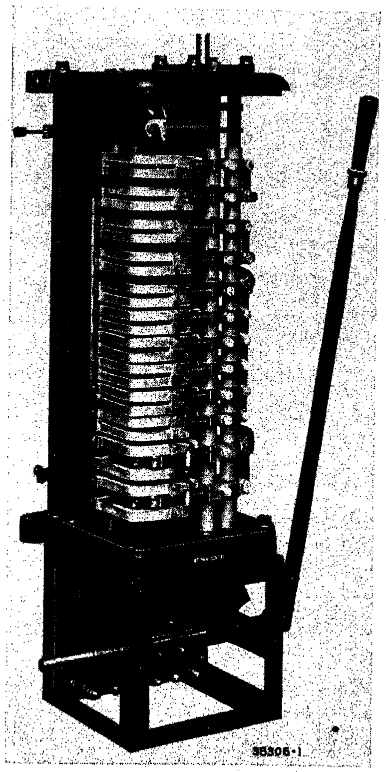


Fig. 19. — Cam-operated hoisting controller with new drive from below, with shield removed.

Mention should be made here of the *completely automatic rack-cleaning machine* put to work in the course of last year in the *Hagneck Power House* of the *Bernische Kraftwerke* and which is entirely electrically controlled. The electric equipment is composed of control gear for hoisting,

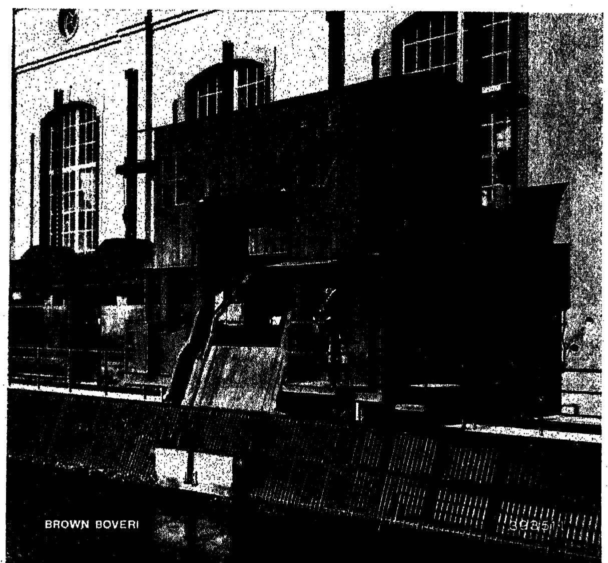


Fig. 20. — Rack-cleaning machine of the Hagneck Power Station, showing the cleaning rake just as it leaves the surface of the water.

for luffing and for travelling with motor outputs of about 30 kW in all (Fig. 20). All the drives are controlled automatically by switching apparatus so that the whole expanse of the rack is cleaned by simply depressing a single push button. After the cleaning operation is over, the rack-cleaner goes back to its original rest position. Under emergency conditions, as, for example, at high water, it is possible to carry out the series of operations such as travelling, hoisting and lowering the cleaning claws, swinging in and out, in any succession deemed advisable, this by individual push-button control. We were able to deliver an identical equipment for the rack-cleaning machine of the *Klingnau Hydro-electric Power Station* belonging to the *Aarewerke* and situated on the River Aare.

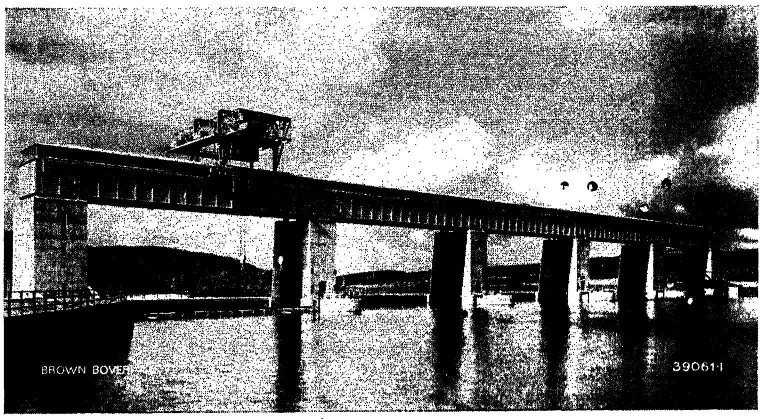


Fig. 21. — Albbruck-Dogern Power Station. View of dam with sluice gates, from upstream.

The *sluice gates of the dam* of the *Albbruck-Dogern Power Station* for which we delivered the electrical control gear were also put to work last year. Squirrel-cage motors built to the high-torque principle were used to drive the five upper and five lower gates. The control is by push buttons, either from the power station or the gangway above the dam (Figs. 21 and 22).

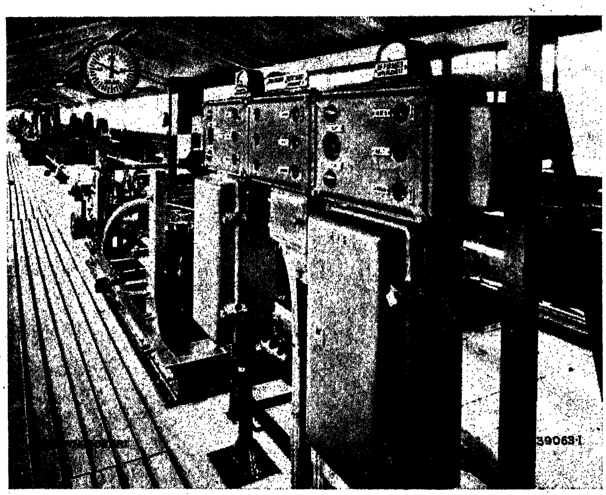


Fig. 22. — Albbruck-Dogern Power Station. Hoisting gear gallery for operating the panels of the sluice gates.

As regards *apparatus for winding engines*, the safety and protection devices for big winding engines have been perfected, in the course of the past year. Very interesting *control apparatus* for *mine hoists and small winders* have been brought out, among which the *depth indicator* shown in Fig. 23. This consists of a cast-iron pedestal designed like the housing of a standard motor, on which is mounted an angle-iron framework to take the spindles of the depth indicator and the rod of the bell. These are driven by bevel gear, either separately or together. The bevel gear is lodged in the pedestal. Instead of combining the depth indicator with a complicated travel regulator which brings back the control lever automatically at the end of the upwards travel and inaugurates electrical or mechanical braking, the arrangement here is such that the run out is made in so far independent of the operator by two or even three points of the run out of the cage being controlled by a centrifugal switch of our well-known design.

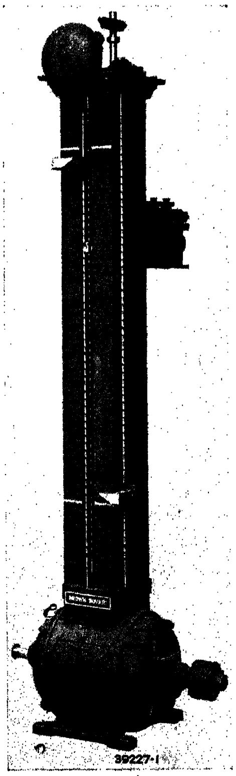


Fig. 23. — Depth indicator, for mine hoists and small winders.

Further, two types of small *safety brakes* have been developed which satisfactorily meet all requirements regarding quick action, absolute reliability and the elimination of hunting. The drop-weight damping device is practically the same as that of the safety brakes of big winding engines. The damping device in question eliminates hunting. This is because the drop weight, made up of the damper housing, its contents and the brake plates which hangs elastically on the brake-weight rod by a stretched spring, and is accelerated by the free fall, causes compression of the above mentioned spring at the moment

the brake shoes are applied. The stored kinetic energy due to the free fall is then gradually discharged on the damper spring. An oil cataract built into the damping device regulates the succeeding stretching of the spring and brings it gradually to the tension it was under before action. Simplicity was aimed at in this design and it was carried out so that the brake could be lodged in as small a space as possible. The release electro-magnet is built on directly here, and thus complicated transmission and interlocking rods are eliminated, which is an advantage over the usual types of brake-lifting electro-magnets. The plant is made much simpler and it is made absolutely reliable.

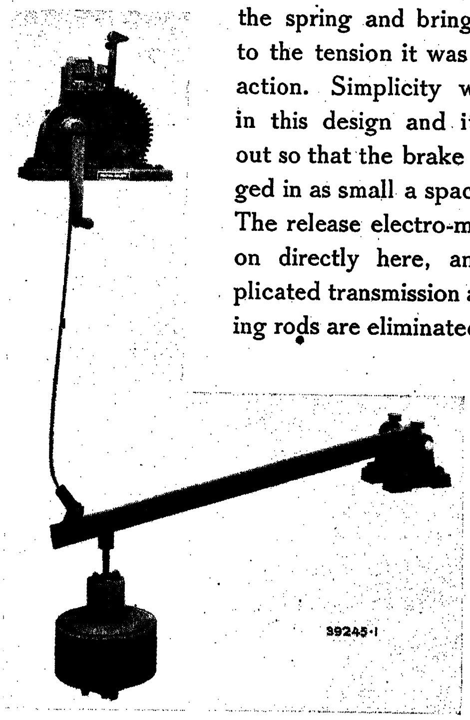


Fig. 24. — Safety brake for mine hoists and winders with built-on release electro-magnets.

Fig. 24 shows one of the safety brakes in applied position. It is designed for small winders with a drop weight not exceeding 120 kg, the maximum fall travel being 400 mm. The brake is essentially composed of a winch with drum to which are suspended by a steel cable the brake lever and drop weight. Fig. 25 shows the other safety brake for a drop weight not exceeding 600 kg and a maximum fall travel of 300 mm. It is designed for separate guiding of the weight damper

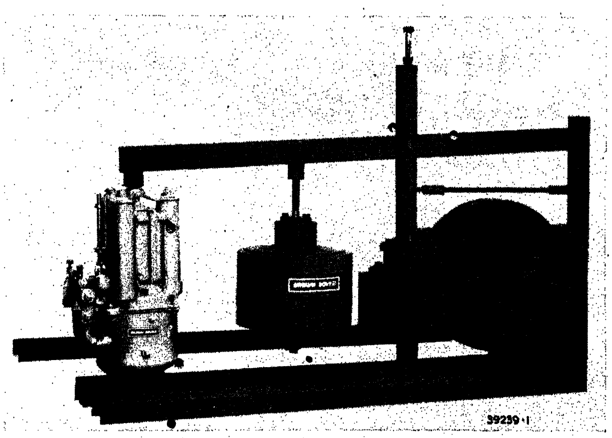


Fig. 26. — Electro-hydraulic thruster acting as brake lifter.

and for individual guiding of the latter, in which case the guide is lodged in the frame of the brake and the guide rod is eliminated. This last design makes the brake very suitable for being built into crane winding gears. The chief characteristics of our safety brakes are that the brake weight applies the brake directly without having to overcome the resistance of intermediate organs and interlocks. Absolute reliability is the result of this.

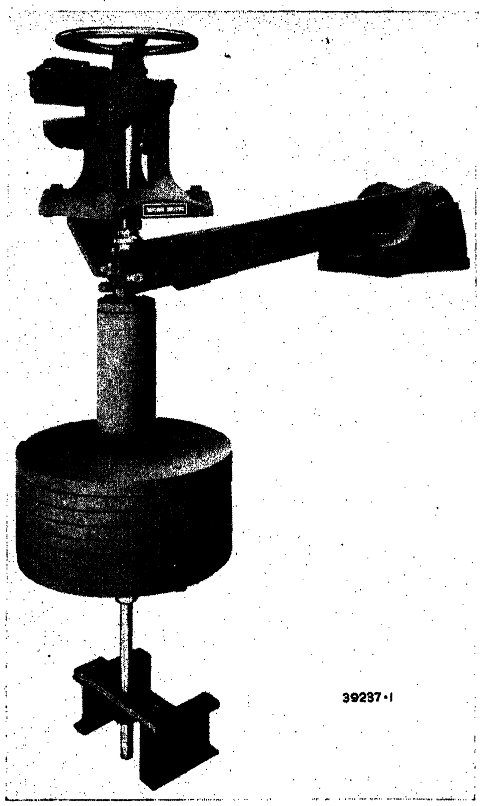


Fig. 25. — Safety brake for mine hoists and winders designed as a quick-acting brake with built-on release electromagnets.

A very interesting novelty in the field of control apparatus for mine hoists and small winders is the *electro-hydraulic thruster* (Fig. 26). This was designed for the following reasons:— There are limit cases about the middle of the power range of small winders (which goes up to about 350 kW), where a foot-operated brake acting as it does on a reduction gear, and used as service brake, no longer suffices, but where it is not possible to put in compressed air brakes acting on the main drum of the machine. To meet these cases a solution

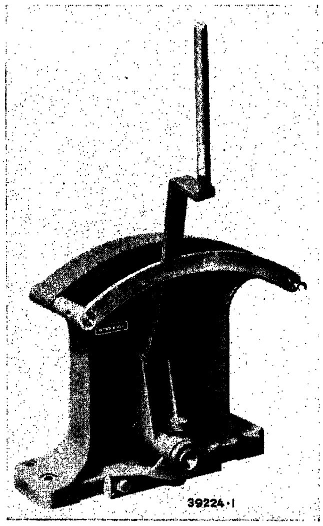


Fig. 27. — Single-lever control stand for mine hoists and small winders.

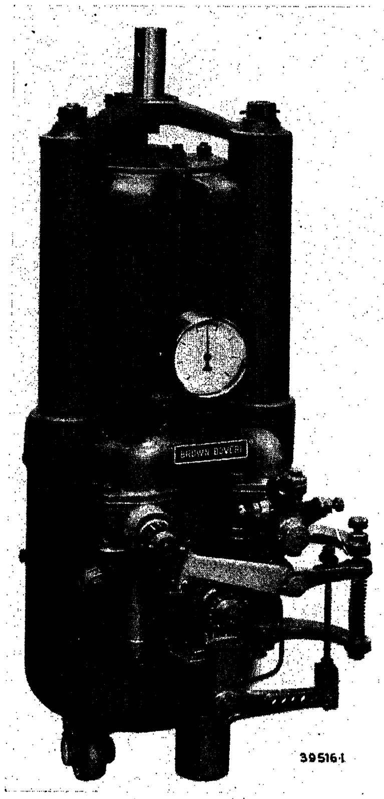


Fig. 28. — Oil counter-pressure regulating brake.

is possible by making the first brake strong enough for manœuvring purposes only and by meeting the safety regulations by means of an additional brake weight which is kept free during the travel by a brake raising device and which acts when the control lever reaches its rest position at the end of the travel of the hoist or, if necessary, during the travel. To replace the brake-lifting electro-magnets, used up till now, for lifting work up to about 700 cmkg or the motor type of brake releaser used for bigger lifting work, we have developed the *"electro-hydraulic thruster"*, which allows the application of the brake, in an advantageous manner, according to a time/travel curve with a bend point in it. This latter consists of two parts one of which falls steeply to the bend point and the other which begins at the bend and is more gradual. The brake weight falls without damping in the steep section of the curve until the brake shoes apply to the brake disc (bend point) and from this point damping is initiated. This ensures quick application of the brake without shocks or hunting.

The setting of the position of the bend point in function of the distance of the brake shoes from the brake disc and the ratio of the brake rod, as well as the necessary and desirable amount of damping after the bend point can be adjusted easily and as desired and without dismantling the gear.

Fig. 26 shows the electro-hydraulic thruster as brake lifter in connection with a reduction gear brake and for the applied position of the brake.

To-day, compressed air brakes are generally required to allow of regulation. This means an air-brake regulator so designed that the pressure in the brake cylinder is in relation with the displacement of the brake lever, that is to say, the lateral displacement of the control lever must be in conformity with the pressure exercized by the brake. A compressed-air brake requires a compressed-air plant with compressed-air container, piping and auxiliary apparatus. For all cases where a foot brake no longer suffices and a compressed-air brake would make the plant too expensive, we have developed a service brake which does not require compressed air and is, nevertheless, fully as good as the compressed-air brake, as far as the possibility of regulation is concerned, while being superior to it in simplicity. This brake is also cheaper to purchase and to operate. This is the so-called *oil counter-pressure brake* which utilizes the electro-hydraulic thruster, mentioned before, with an altered sluice-valve addition (Fig. 28).

Finally mention should be made of a new *single-lever control stand* developed on the lines of our well-known single-lever control stand, but which is simpler and lighter. It is intended for use with mine hoists and small winders (Fig. 27) and should find an application in plants where the controller is under the floor or for some reasons placed at some distance from the operator's stand.

(5) *Electric ship propulsion and electric auxiliaries for ships.*

a) *Electric ship propulsion.*—In our last year's summary we were able to report the successful trial trips of the two Finnish coastal-defence battle-ships "Wäinamöinen" and "Ilmarinen" which are equipped

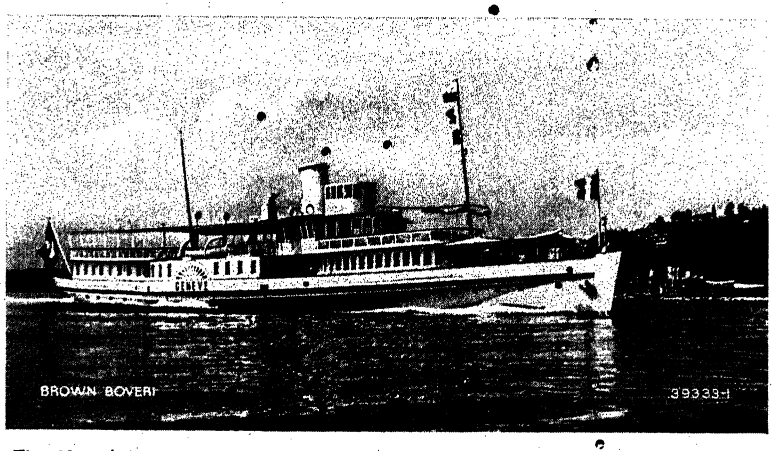


Fig. 29. — Saloon paddle vessel "Genève" of the Cie. de Navigation sur le Lac Léman, Lausanne, with its new Diesel electric drive.

with Diesel-electric propulsion. In the course of the past year, two further vessels equipped by us with electric propulsion have been put into service. One of these is the *saloon paddle vessel "Genève"*, mentioned here, last year, running on the lake of Geneva, the other is the *"Olav Tryggvason" a mine layer* for the Norwegian navy. We will only say a few words on the subject of these vessels, which will be the subject of a more detailed description, to be published later.

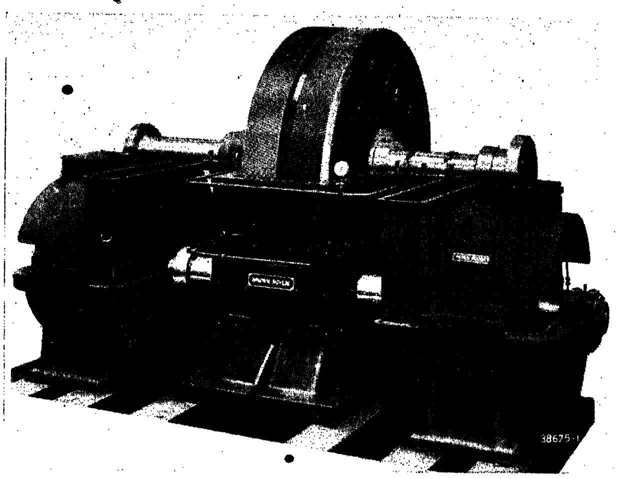


Fig. 30. — Diesel-electric drive of the saloon paddle vessel "Genève" of the Cie. de Navigation sur le Lac Léman, Lausanne. Drive of the paddle wheels by means of a reduction gear, 525/50 r. p. m., 2 D. C. motors, each of 340 kW, 650 V, 525 r. p. m.

As mentioned here, last year, the *"Genève"* (Fig. 29) was transformed from steam to Diesel-electric propulsion and we gave a layout drawing of the machinery and main characteristics thereof. We will only recall, here, that two Sulzer four-cycle Diesel engines of each 530 H.P., 400 r. p. m. were put in, the output of which was transmitted electrically to the existing paddle wheel shaft, the latter being driven by two D. C. motors each 340 kW at 500 r. p. m., through a reduction gear (Fig. 30). Control of the vessel is from the bridge. The steamer was commissioned on the 2nd of September 1934 and the engine plant has given entire satisfaction since then. An interesting feature of this equipment is the use made of a quick-acting Brown Boveri regulator utilized here as a current limiter to protect the Diesel engines and the electric machines against load surges, when manœuvring. This device has proved most useful and allows the officer on the bridge to carry out manœuvring as quickly as he desires, that is to say to carry on just as with the former machine telegraph (Fig. 31) without causing the Diesel engines to be dangerously overloaded. It should also be said that the plant meets all requirements as regards noiseless and vibrationless running.

Fig. 31. — Bridge of the saloon paddle vessel "Genève" of the Cie. de Navigation sur le Lac Léman, Lausanne, with Diesel electric drive.

The *mine layer "Olav Tryggvason"* (Fig. 32) is equipped with a mixed Diesel-electric and geared turbine drive. The Diesel-electric drive is used alone for cruising speeds and both drives together for high speeds, all manœuvring being carried out with the turbine drive while the electric drive works continuously at full load at all propeller speed and without special supervision. This problem found a simple solution by using a Brown Boveri quick-acting regulator working, here, as a current regulator. Further, the regulator is made susceptible to voltage fluctuations in such a way that, when the propeller runs slow, the current supplied is smaller. The Brown Boveri quick-acting

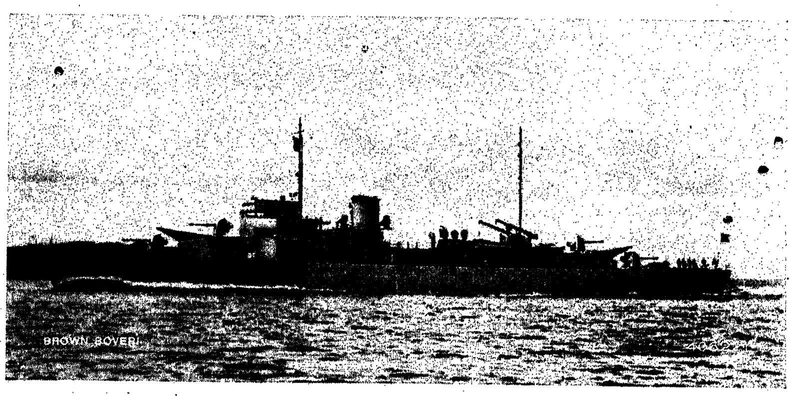


Fig. 32. — Mine layer Olav Tryggvason of the Norwegian navy, equipped with Diesel electric drive.

regulator used here is more economical in service than the constant-current apparatus which has been suggested for this duty and sometimes, applied. In our January number 1933, we gave a general layout drawing of the machinery for a marine drive of this type. In the present case, the output is produced by two 8-cylinder Sulzer Diesel engines each 850 H. P., 530 r. p. m. and is transmitted to the propeller shafts through two propeller motors each 700 H. P. at $\pm$ 190 r. p. m.

In ships having multi-propeller propulsion and, especially, in those driven by Diesel engines as well as in those with Voith-Schneider propellers, ship oscillations may be set up, as has been shown by recent investigations. This happens when the propellers do not run symmetrically, that is to say when the propeller blades are not *symmetrical to the axis of the vessel at any given moment.*

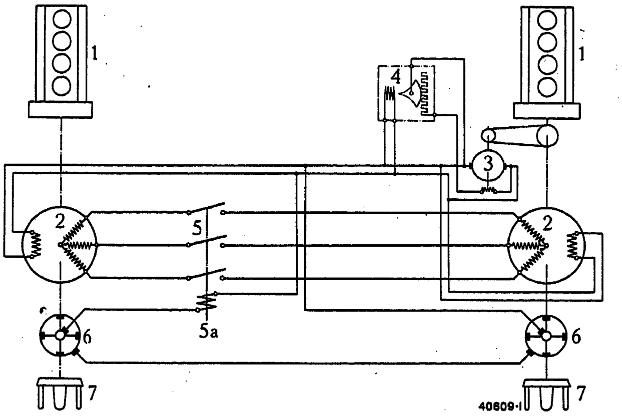


Fig. 33. — General arrangement of a synchronizing equipment for a twin propeller vessel.

1. Diesel engine.
2. Synchronous machine.
3. Exciter.
4. Voltage regulator.
5. Coupling switch.

5a. Switching-in coil for 5.
6. Contact apparatus to actuate 5a.
7. Voith-Schneider propeller.

When the propeller shafts of a twin-propeller vessel are kept symmetrically in step, the forces of corresponding propeller blades acting in a direction vertical to the axis of the ship are of the same magnitude and in opposition at any given moment. The sum of the transverse forces is, therefore, zero and the main cause of vibration is eliminated.

Two independent propeller shafts can best be maintained symmetrically in step by fitting a synchronous machine on each shaft. The stator windings of these machines are then connected together and their pole wheels so fitted on the propeller shaft that, by correct positioning of the blades, electrical synchronism is also possible.

With the propellers symmetrically in step and rotating at absolutely the same speed, no equalizing current flows in the lead connecting the two stators. As soon, however, as one shaft leads on the other by a certain angle, the induced voltages are no longer balanced; the resulting difference causes equalization of the outputs in such a manner that the propellers are again brought into symmetrical step. The angular difference occurring is very small and is in direct ratio to the equalizing load.

In the case of electric ship propulsion by alternating-current synchronous motors, symmetrical running of the propellers in step can be attained by using a special synchronizing device. Devices to this end can also be added to propeller shafts which are direct-driven by the prime mover.

Synchronizing equipments of this type have already been ordered for two vessels having Voith-Schneider propellers. The fundamental layout is shown in Fig. 33.

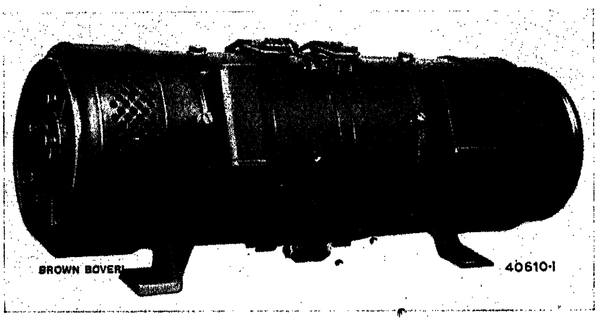


Fig. 34. — Converter set for wireless transmission stations on board ship.

b) *Electric auxiliaries for ships.* — The converter sets shown in Fig. 34 form an interesting new development in the field of wireless transmission stations on board ship. The transmission valves used on ships call for D. C. service voltages of several thousands of volts and also, according to the system used, either high-frequency A. C. voltages or low D. C. voltages. These different kinds of voltages and values call for special converter sets to produce them. The set shown in Fig. 34, for example, is composed of a high-voltage D. C. dynamo, 3000 V, a high-frequency A. C. generator of 500 cycles and of the D. C. driving motor. In order to meet the requisite conditions of weight and saving of space, which are called for, especially, on warships, all the machines making up the set are built together to form a single block (monobloc design). Similar converter sets are also built for low voltage D. C., the dynamo being designed as a double commutator machine for 12 and 18 V. More than 60 of these converter sets were sold, in

a very short time, by one of our concessionary companies.

Other interesting innovations in design in the field of marine auxiliaries are:—the electrical equipment for 2 electro-hydraulic steering gears, control of the motors being by push-button from the bridge, as well as from the steering gear chamber. Owing to its vital importance, the steering equipment for a rudder is composed of 2 pump sets which can work singly or together; if only one set is in service, the second set takes over duty, automatically, if the first set stops.

It has already been said (under "Electric ship propulsion") that a large number of auxiliaries were delivered for the mine layer "Olav Tryggvason" besides the electric propeller drive for cruising speeds. There were 54 of these auxiliaries:—Diesel-dynamos, drives for pumps, fans, compressors, anchor winches, mine-raising drums, life-boat winches, as well as converter sets for search lights and mine-telegraph equipment.

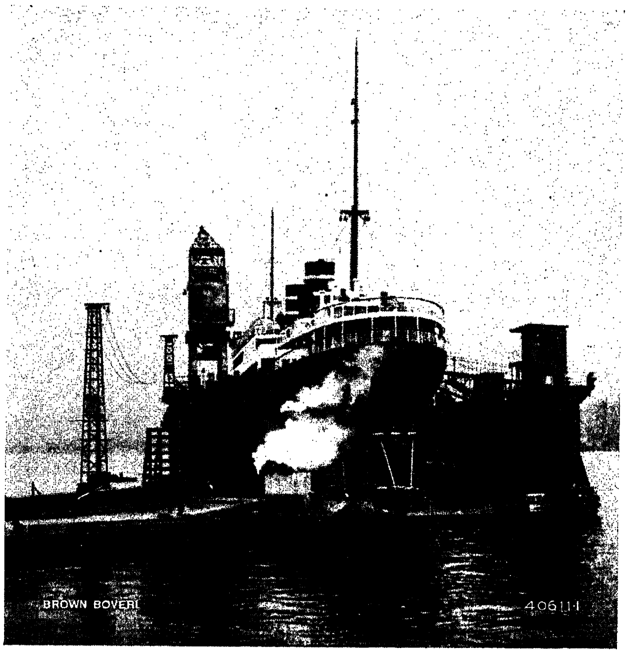


Fig. 35. — Floating dock with electric equipment.

A significant indication of the tendency towards the electrification of ships is the fact that, in the course of 1934, we and our concessionary companies received orders for, and placed, about 6600 kW of D. C. turbo-dynamos and about 5200 kW of D. C. Diesel-dynamos for marine purposes.

Our D. C. quick-acting regulator is being utilized more and more frequently and especially on warships; it has proved impervious to vibrations and is used as a voltage, current and speed regulator, etc. The apparatus has manfold uses and allows of a simple solution of otherwise complicated tasks.

Mention should also be made of the electric equipment delivered for a *floating dock* capable of raising 8500 t. This dock is 152·4 m long and 30·5 m wide and was put to work at the beginning of 1934 in Bergen (Norway). It is equipped with material delivered by the *A/S. Norsk Elektrisk & Brown Boveri* (Figs. 35 and 36).

Power is tapped from the municipal supply under the form of three-phase current, 220 V, 50 cycles and is led into the dock through 6 cable leads each of 150 mm² section, which are so suspended as to allow of movement (see Fig. 35, left-hand side). Distribution equipment is lodged in the lower storey of the switchgear house, which can be seen on the right-hand side of the dock. The most important machines for service are two pump sets to empty the dock when it has to be raised. The two pumps, built to special dock design *(A/S. Kvaerner Bruk)*, are lodged in the lower part of the dock and driven by vertical shaft motors placed on the upper part. Each of these motors is for 60 kW at 600 r. p. m. and can be overloaded by 25 % for two hours, according to regulations of the British Standard Institution; they are amply dimensioned for the duty required of them. They have deep-slot rotors, are not harmed by being frequently started up at short intervals and are, thus, very reliable.

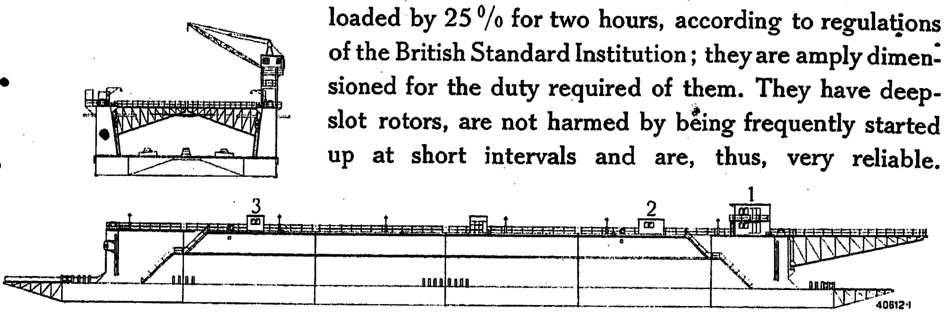


Fig. 36. — Floating dock with electric equipment.
1. Switchgear house. 2. Main pump I and fire-extinguishing pump. 3. Main pump II.

Starting is by star-delta switches combined with oil circuit breakers, changing-over being under no current; they have over-voltage and no-voltage release and can be tripped by push-button from the switchgear chamber. A small scavenging and fire-extinguishing pump is mounted beside the main pumps. The driving motor of this pump is of 25 kW, 1000 r. p. m. and it is equipped similarly to the main motors. The travelling crane, seen on the left hand side of the dock, in Fig. 35, is equipped with standard spray-

water proof motors. There is a converter set in the lower storey of the switchgear house, composed of a three-phase motor 70 kW, 1500 r. p. m. with a deep-slot rotor and coupled to two D. C. dynamos each 32 kW, 110 V; these dynamos can be connected in series or in parellel. This converter set supplies current to the ship lying in the dock at a voltage suitable to that of the vessel in question and it also supplies the four warping winches of the dock used to draw the ship into the dock and, to allow of regulation, are driven by D. C. series wound motors, 11 kW, 220 V. There is, also, a 10-kVA single-phase transformer, besides the converter set, to supply current to the vessel in dock; it has tappings for the standard ship voltages. This transformer is used when the lighting power requirements of the vessel are small.

Finally, it should be said that the interior of the dock is divided up by water-tight partitions into 20 parts. Each of these chambers can be connected up to the pumps by pipes and valves or connected to the surrounding water. Each chamber is opened or closed by a remote-controlled valve and all these valves can be operated from a desk panel in the switchgear house. This desk was delivered by the specialist firm Rud. Meyer and is equipped with a diagram of the systems of pipes and with water-level indicating instruments for all the chambers. It is, thus, possible to control from this point whether the dock is sinking or rising uniformily. There are also instruments here to control the load on the two main-pump motors, as well as the push-buttons for tripping, already mentioned.

(6) *Transformers.*

Several big transformers were built by us and our concessionary companies in the course of last year. Fig. 37 shows one of three 20,000-kVA three-phase transformers with natural cooling and for outdoor erection, 10·5 kV/145 kV built for the *Klingnau Power Station* of the *Aarewerke A. G. in Brugg (Switzerland).*

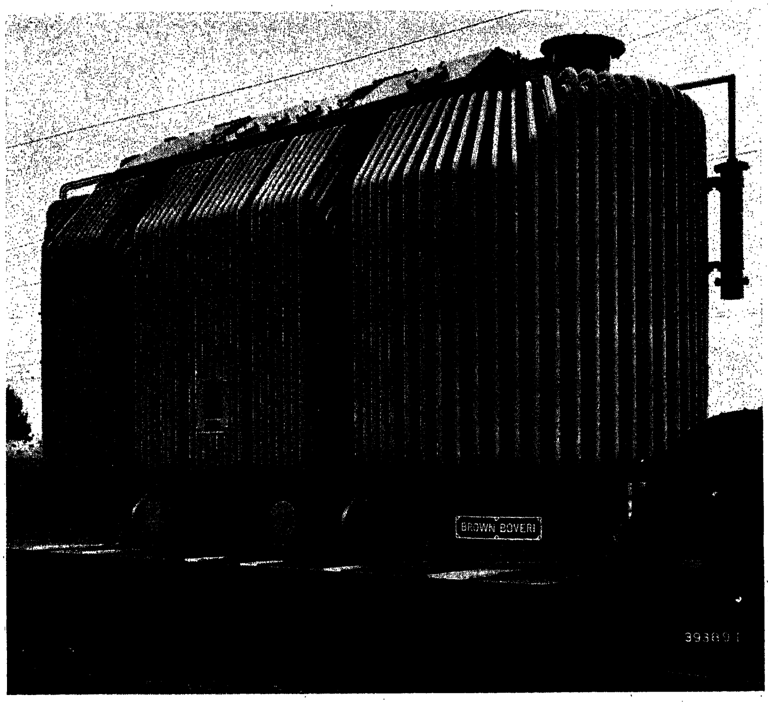


Fig. 37. — Three-phase oil-immersed outdoor transformer, 20,000 kVA, 10·5 + 5%/145 // 10·5 + 4%/116 kV, placed on the low-swung truck for transport to the Klingnau Power Station of the Aarewerke A.-G.

Two three-phase regulating transformers with natural cooling were also built for the *Hauterive Power Station* of the *Entreprises Electriques Fribourgeoises.* These are 11,000-kVA units, 127 kV ± 5 %, 60 kV ± 5 % for changing over to 34·7 kV ± 5% with a third delta-connected compensating winding for 2000 kVA.

These transformers, which have to transmit power in both senses, form the connecting link with the system of the Energie Ouest-Suisse. The town of Lausanne put two three-phase regulating transformers into service, as well, which are placed in the Bois-Noir Power Station. These have also got natural cooling and are of 8000 kVA each, 6·3/132 kV; the latter voltage can be regulated in 10 steps of each 1320 V, above and below.

An interesting transformer is one intended for the Town of Lausanne, for the Bois-Noir Station, which is built for 1200 kVA inherent output and 8000 kVA through-going output. The duty of this unit is to distribute the watt load through two parallel lines. The transformer consists of two transformers in one tank, namely:— the excitation transformer in auto-transformer connection with regulation in ± 10 steps and the series transformer. In order that the voltage regulation should be effective in the closed ring which is formed by the two lines in parallel the additional voltage generated by the series transformer must have a given phase position with regard to the voltage of the system. As the lines in parallel work through transformers, the ohmic re-

sistance of the closed ring system is low as compared to its reactance. The vertical position of the series transformer additional-voltage vector to that of the system-voltage vector is attained by suitable choice of the excitation transformer connection and that of the series transformer. The design which results from the group of two transformers can justly be termed *cross-regulation transformer.*

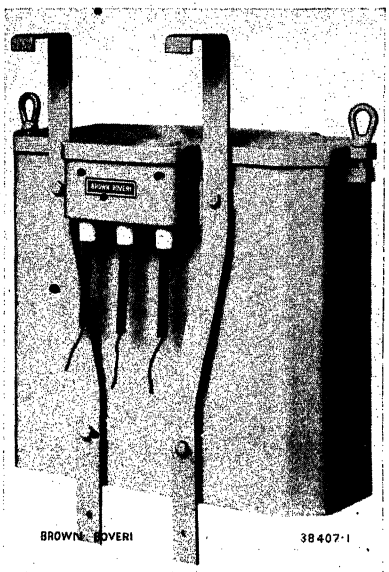


Fig. 38. — Three-phase oil-immersed auto-transformer, 90 kVA, 4500/5600—5000 V, 50 cycles.

Among the units built by our concessionaries, mention should be made of two three-phase transformers with external oil circulation and water cooling, each for 15,000 kVA, 23,5/9 kV, 42 cycles for the *Piazzale Trento plant* of *Azienda Elettrica Municipale* in *Milan.*

An interesting development in transformer design is the creation of a series of *single and three-phase transformers of low output* up to 60 and 84 kVA respectively for outdoor mounting and having a hook device to allow of hanging them on wooden poles. As shown in Fig. 38 the new design differs from former outdoor designs for low outputs in the following respects:—There are two suspension hooks on the high-tension side which are removed during transport. Two lifting rings, on either side of the cover allow of hoisting the transformer up on the pole, after which the hooks are suspended on the cross piece. The lifting rings also serve to bolt down the cover thus rendering the transformer weather-proof. The high-voltage bushings are fitted on the same side as the suspension hooks and the low-voltage bushings on the opposite side. For connection, porcelain bushings screwed in from the interior and lengths of flexible cable are provided. Connection between the cable ends and the incoming and out-going lines are made by soldering or clamping. The tank is provided with an oil drain screw underneath and a plug screw on one side; a temperature measuring device can be fitted in place of this screw.

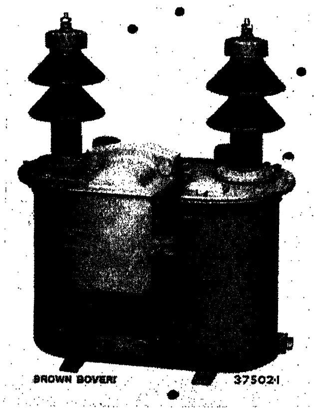


Fig. 40. — Voltage transformer Type TMF 42 for outdoor mounting.

Small transformers can be designed with cable-end boxes if required (Fig. 39).

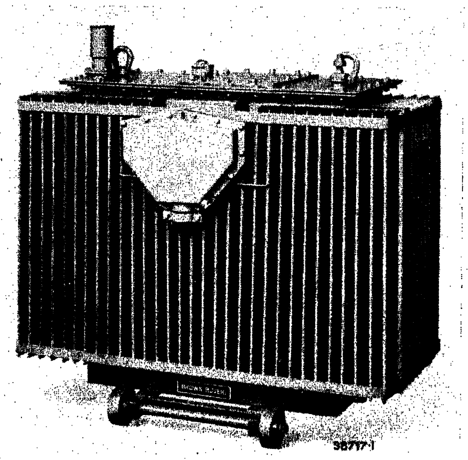


Fig. 39. — Three-phase oil-immersed outdoor transformer with cable-end box, 250 kVA, 11,825—11,000 (10,725)/415 V, 50 cycles.

The design of the series of oil-immersed *single-phase-voltage transformers* for indoor and outdoor mounting was improved, for rated voltages up to 64 kV (Figs. 40 and 41).

The most interesting transformer type brought out, lately, is certainly the *transformers with continuous regulation on the low-voltage side.* Their creation is due to the fact that regulating transformers with on-load tap-changing switches are a practical proposition for all high-voltages encountered in practice but an entirely satisfactory low-voltage regulator has, hitherto, not been placed on the market. The majority of such apparatus operate on the principle of the regulating transformer with on-load tap-changing switch. For reasons of space and price, these could only be built with a limited number of steps and step voltages of two and more per cent had to be tolerated. The result was that voltage regulation was very uneven and took place with considerable

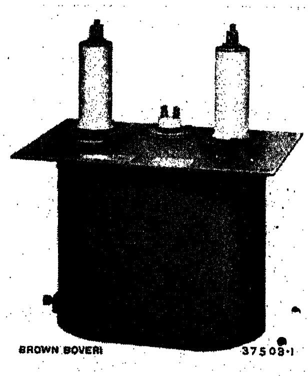


Fig. 41. — Voltage transformer Type TW 42 for counter-sunk mounting.

time lag. Induction regulators form another solution of the problem; these give continuous regulation but are expensive and clumsy, and, further, the regulated voltage is displaced in phase with regard to the unregulated voltage.

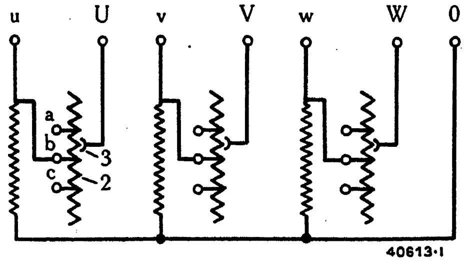


Fig. 42. — Fundamental diagram of connections of a three-phase low-voltage regulating transformer according to Fig. 43.

We have now evolved low-voltage regulating equipment with which the advantages of the regulating transformer are combined with those of the induction regulator. Fig. 42 shows a fundamental diagram of connections of our new regulating transformer. The primary and secondary winding of the regulating transformer, designed as a booster transformer, are connected together in auto connection. By connecting up the connection leads to the terminals a, b and c of the regulating winding 2 the regulating range can be made to suit the service conditions pertaining, within certain limits. The system subject to the smaller variations is connected to the exciter winding with terminals u, v, w. Contact 3 built as a trolley runs along the whole of the spirally wound and bare regulating winding 2 guided by a current rod connected to terminals U, V, W. The active part of one phase is designed as a single-phase shell-type transformer. The middle leg carrying the winding is broken by a gap at its centre and in this gap the current rod carrying the contact apparatus moves. Each half leg carries a disc winding and the excitation winding is inserted between the turns of the regulating winding which are, thus, kept apart. The two halves of the excitation winding are connected in series and those of the regulating winding in parallel. The electric connection between the contact device, or current collector, and the current rod is a flexible length of cable. The current collector is a U-shaped centre piece with two contact pieces in each leg. A spiral spring gives the necessary contact which is increased by the electro-dynamic force of the current obtained by the special form of the current collector. Single-phase units can be assembled into multiphase regulating transformers by means of insulating couplings (Fig. 43). The complete active part is suspended from the cover and placed in an oil tank of corrugated iron sheeting. The bushings are fitted on one longitudinal side of the cover for the regulated side and on the other for the unregulated side.

The control gear is mounted on the cover of the oil tank; an automatic motor control being used as standard practice. The mounting of the complete control gear on the tank makes the regulating transformer a self-contained unit. For setting to work, it is merely necessary to connect up the incoming and outgoing leads, as in an ordinary transformer. The drive consists of a small driving motor on the cover directly fed from the regulating transformer so that no auxiliary source of current is required. The motor shaft is provided with a worm gear which drives the regulating shaft through a slip coupling. The torque of the regulating shaft is transmitted to the shaft of the regulating transformer by roller chain gear. The oil-immersed chain wheel is mounted insulated on the live shaft of the transformer. The worm gear with its mechanical travel-limiting device for both end positions is mounted in a box which is fitted on the cover and filled with oil. The limit switch for the driving motor is also lodged in this box. The driving shaft is extended so that it can also be manually operated by a removable crank. If required, the regulating transformer can be supplied merely with hand control provided with limit stops.

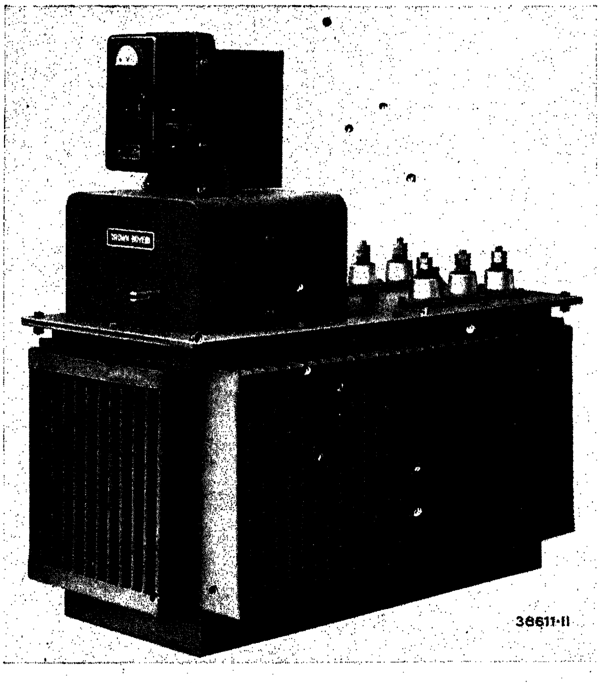


Fig. 43. — Three-phase low-voltage regulating transformer, through-going output 200 kVA, 380 volts, 50 cycles.

As control organ, relay type Q 2 is used, which usually is adjusted so that it operates when the regulated voltage deviates $\pm$ 1 % from the value to be maintained constant. For special purposes, it can be adjusted considerably more finely. If the regulating transformer is to be used for compensating the voltage drop in the outgoing line, regulation can be accomplished with an overcompound characteristic. In this case, an additional current transformer is required. The control relay, like the driving motor, is fed from the regulating transformer so that no special voltage transformer is needed.

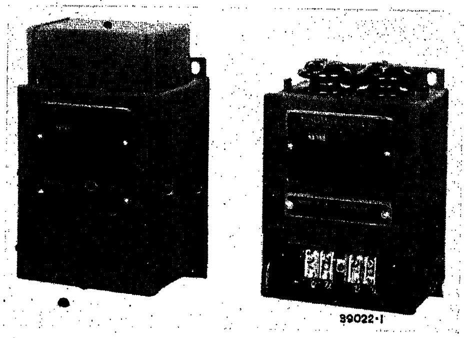


Fig. 44. — Single-phase ignition transformer for oil firing, 240/120 // 10,000 V (for connecting up to primary voltages of 220—250 V, as well as to 110—125 V), 50 cycles, 250 VA.

Up till now, we have brought out 6 different types, for 100, 125, 200, 250, 400 and 500 kVA through-going output and up to 550 V low voltage, with a regulating range referred to no-load voltage of either $\pm$ 8·5 % or from + 12 and — 5 % or — 12 + 5 % respectively.

Voltage regulation is absolutely gradual, i. e. without steps and sparking. Thus the electric quality of the transformer oil is not affected.

We think the new regulating process has a promising field of development in single-phase traction service where speed regulation of the motors is attained by altering the supply voltage.

Finally, mention should be made of *new ignition transformers* for oil firing, of 200 VA and 10,000 V high voltage, which can be wound for any primary lighting voltage met with in standard practice (Fig. 44).

(7) *Electric arc welding.*

Two years ago, we referred, for the first time, in our yearly summary to our new instantaneous-reaction *D. C. arc-welding machines*, which are built, to-day, in series and in three sizes (Fig. 45). These machines have given an excellent account of themselves and are suitable for all kinds of iron welding and, especially for welding the numerous kinds of rustless steel (chromium-nickel alloys, etc.) on the market, as well as brass, bronze, aluminium and its alloys. These machines are advantageous for carrying out vertical and overhead weldings which it is, otherwise, difficult to do properly. Generally, the generator is built together with an A. C. or D. C. motor so as to form a single-housing converter of rugged, rainproof design which is sold for stationary duty or as a portable unit. The welding generators, however, can also be belt driven or driven by petrol or Diesel-engine. The smallest type designed during last year, for currents of about 10—160 A, is suitable for light work, chiefly for welding thin metal sheets; it is chiefly used in coach works, sheet metal works, garages, etc. The medium sized type, for 30—350 A, is used for every kind of welding work, namely, in fitting shops and smithies, repair shops and factories of various kinds. The third type is for strong-current welding, of about 50—440 A, therefore for heavy work. In some cases, it is very useful if a plug device is provided to allow two of our sets to be *connected in parallel without difficulty* thus permitting of using welding electrodes of big diameter (up to 12 mm). Usually, one welding set is used on each welding site, but for work demanding currents up to about 600 A, for welding with thick electrodes, two sets in parallel must be used. Our new *remote regulation is* also a very useful inovation which allows of continuous adjustment of the current, this from a point remote from the generator, with the help of a small regulating resistance. By being able to adjust the current rapidly from the welding site itself, time is saved and a current of continuously suitable strength is attained. Remote control of the welding current is used advantageously in building frameworks, in the welding of big parts such as

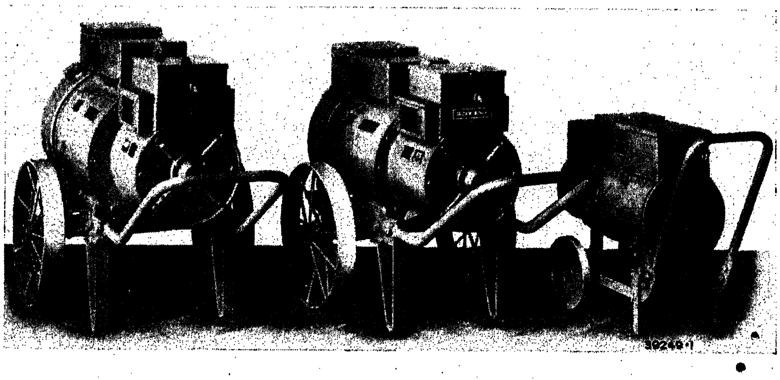


Fig. 45. — Brown Boveri arc-welding set of instantaneous-reaction type, in 3 sizes for 10—160, 30—300 and 50—440 A.

boilers, containers, pipes, as well as in tunnel and in marine constructional work, that is to say, wherever it is not convenient or is impossible to place the welding set beside the welder.

Apart from single welding sets, we build welding plants to allow of welding on several sites at once, which is useful in big works. A large number of these sets have been used successfully for several years, now. Thus, we delivered to one of the most important shipyards a welding plant with distribution to 160 welding posts, along with the requisite regulating apparatus. In these 40-V welding plants, a big number of welding posts are connected up to

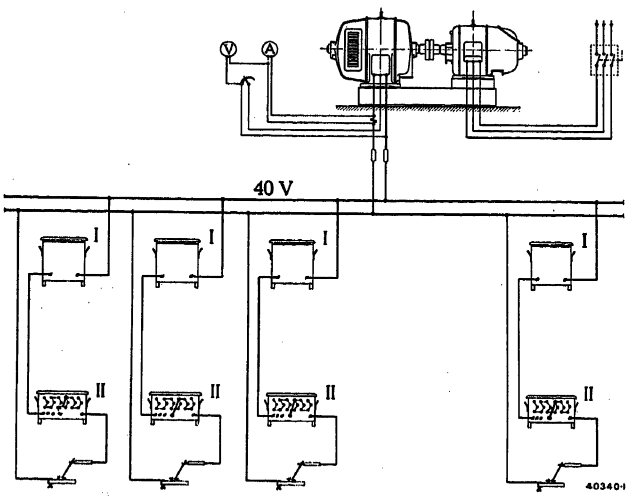


Fig. 36. — Fundamental diagram of connections for a welding plant, 40 V, allowing of welding on several sites at once, with ohmic-inductive welding current regulators.

one or several flat-compounded generators in parallel, the connections being carried through special ohmic-inductive welding-current regulators. These allow of adjusting the welding current desired, while eliminating mutual perturbations, they also impart stability to the arc, i. e. a sufficient ignition voltage (see Fig. 46). There is a regulator set for each welding site consisting of two parts:— one part near the distribution bus-bars of the plant and a second, the regulator proper, put close to the welder. The distribution bars of big plants are, often, several hundred of metres long and are laid in the shops, on the quays of the shipyards, etc.

Our *welding transformers* have been redesigned so that the welding currents can now be regulated quite gradually, i. e. *without steps* or troublesome vibrations. This result is attained by means of a specially designed stray-flux leg, in two parts, forming a part of the magnetic core. Apart from this advantage, our welding transformers are very small and relatively light. Up till to-day, we have turned out two types of these transformers, one for 25—135 A and the other for 50—220 A (Fig. 47). The first type weighs only 65 kg and can be carried while the second, weighing 130 kg, is mounted on a truck. Both types allow of connections being changed over to permit of their being supplied from different service voltages, which makes them useful. Thanks to their *extraordinary good welding qualities*, iron sheeting as well as angle pieces of forged iron or cast steel can be welded, repairs on cast-iron or cast-steel pieces carried out.

Electric-arc welding has found an important place for itself, to-day in machine and apparatus shops in the manufacture of pipes and containers, in iron

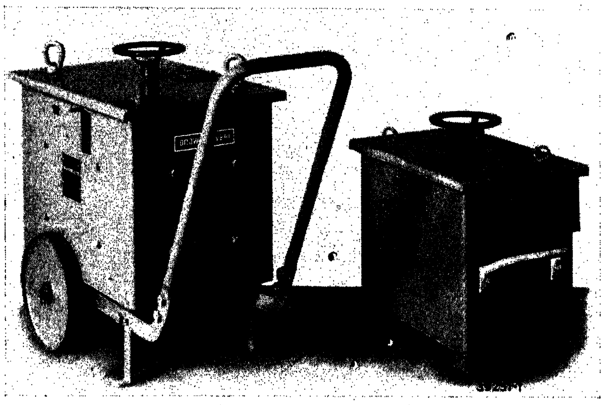


Fig. 47. — Welding transformer with smooth welding-current regulation, for 25—135 and 50—220 A.

building framework, for connecting the iron framework of reinforced concrete, in making sheet-metal utensils of all kinds. It has been the cause of valuable technical and economic improvements.

(8) *Brown Boveri power mutators.*

The development of the power mutator has made great strides in the course of the past year, thanks to intensive and fruitful research work. Detailed information on this subject was given in our June number and, just lately, in the December number of last year, so that a very short summary will suffice here.

We would recall, to begin with, that the problem of the universal utilization of the mutator as a static converter for single or for multi-phase A.C. into D. C. and vice versa and as a converter of single or multi-phase A. C. of one frequency into single or multi-phase A. C. of another frequency has been solved in an entirely satisfactory manner. To-day, every

problem set by the requirements of practice in the field of the flexible coupling of D. C. and three-phase systems as well as of the coupling of three-phase systems of different frequencies, in order to allow of power interchange, can be realized.

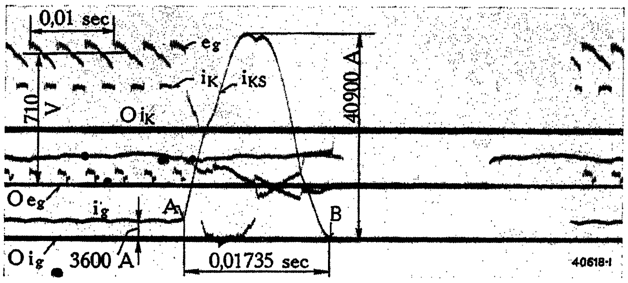


Fig. 48. — Extinction of a short-circuit current of 40,900 A peak value occurring in an A.C.—D.C. mutator with grid control.

Further, anode grid control allows of absolutely reliable extinction of back fires and the suppression of short circuits. The oscillogram of Fig. 48 shows how a short-circuit current in a mutator, 710 V, which has risen from the rated 3600 A value to a peak of 40,900 A, is extinguished by grid control within 0·01735

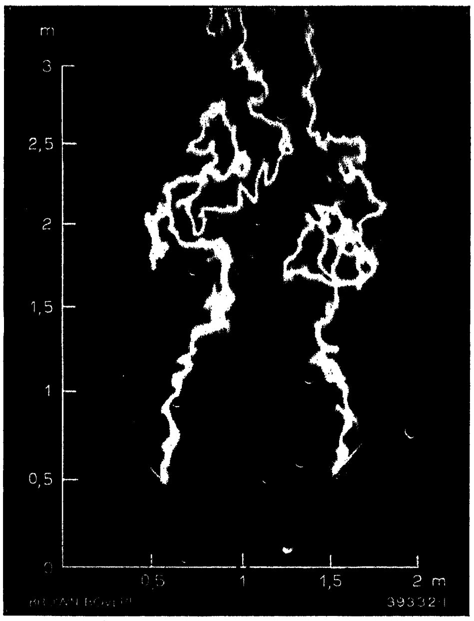


Fig. 51. — Arc when rupturing the D. C. circuit of a high-voltage mutator 50,000 V, 41 A.

seconds. Especial interest attaches to our achievement, in the past year, of generating a D. C. voltage of 50 kV in a single three-phase D. C. mutator (Fig. 49), this after 35 kV had long been considered the highest figure attainable. Fig. 50 shows the high-voltage mutator on the test bed; Fig. 51 shows a D. C. 50-kV and 41-A are produced with this mutator.

This is a milestone in mutator development because it puts the question of the transmission of big quantities of power over long distances by means of high-voltage D. C. on a practical basis of discussion. It would seem possible — at least in principle — that an arrangement comprising 6 mutators of 50 kV, 333 A, connected in series and fed by two 50,000 kVA transformers, would enable an output of 100,000 kW at 300 kV D. C. to be transmitted from the generating station. Under these conditions and with the middle voltage point earthed it would be necessary to insulate the high-voltage transmission lines, or cables, against earth for a voltage

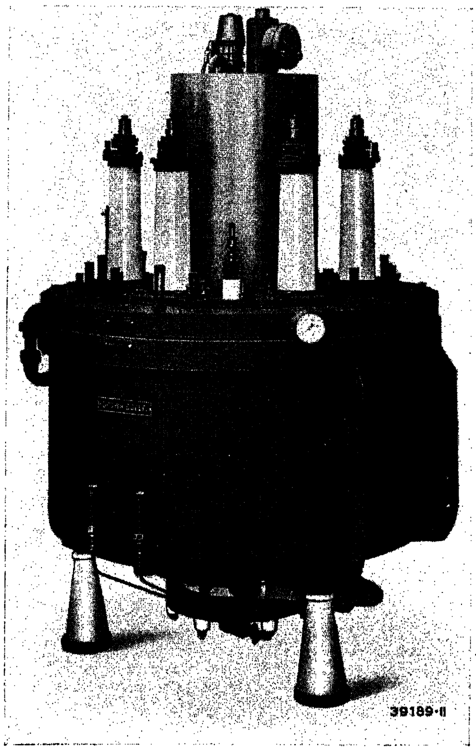


Fig. 49. — High-voltage mutator, 50 000 V D.C.

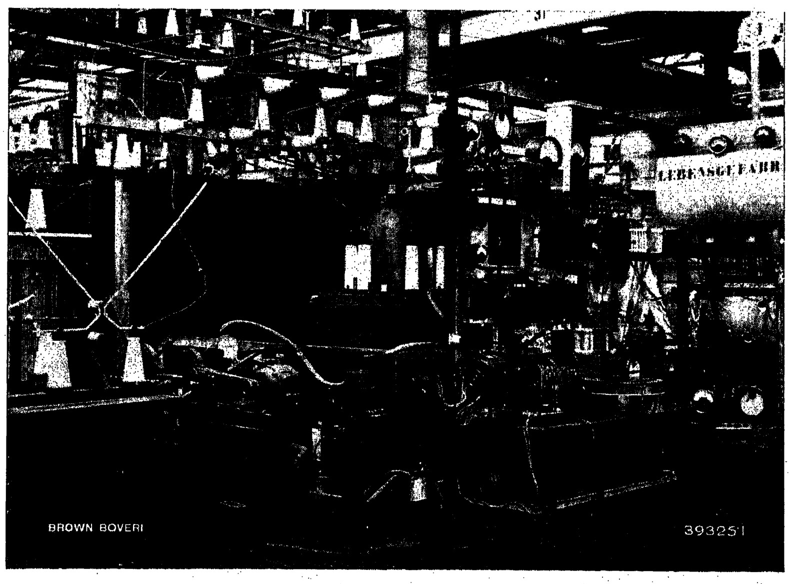


Fig. 50. — Test bed of high-voltage mutator, 50,000 V D.C.

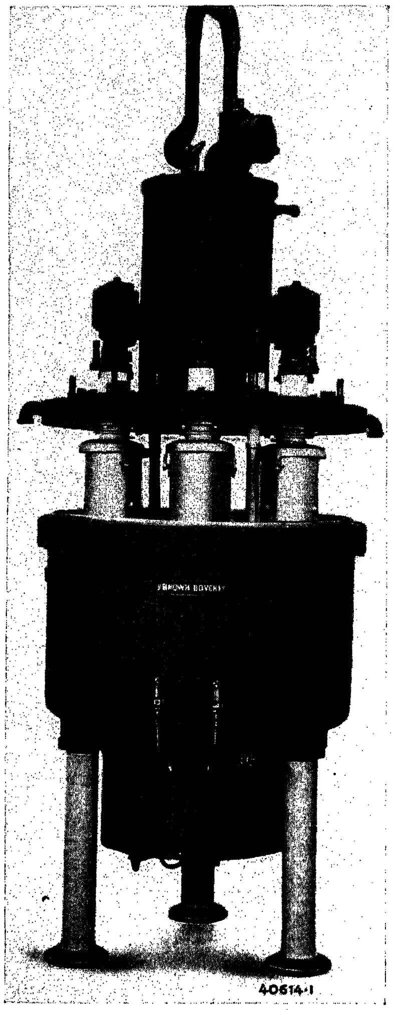


Fig. 52. — Mutator with hot cathode.

of 150 kV. A test of this kind is, however, beyond the scope of a manufacturing plant. For this reason, we take the opportunity, here, of drawing the attention of all concerned, particularly of power producer circles, to the matter, with the hope that they may see their way to give their valuable assistance in an experiment on a large scale and thus collaborate in working out of a problem the solution of which is going to be, sooner or later, of vital importance to them.

Among the various designs of electric mutators, we have devoted our attention to the *vapour-filled hot-cathode mutator* as well as to the one with mercury cathode, because the former is characterized by a smaller voltage drop than the normal mutator and is, for this reason, very suitable for low-voltages. Fig. 52 shows the first hot-cathode mutator built by us which has been in practical service for some time and, with its 600-A cathode current, is probably the biggest hot-cathode mutator built up to date.

Among the mutator plants ordered in the course of 1934 for working in both senses of power flow, mention should be made of the units for the *Van Reenen and Colworth Halt Substations of the Electricity and Supply Commission of the Union of South Africa*. These substations supply power to the Natal line of the South African Railways. Mention should also be made of the *S. Viola-Bologna*, substation of the *Italian State Railways*. Fig. 53 shows the fundamental diagram of connections of the first two substations with 3 mutator for a rated voltage of

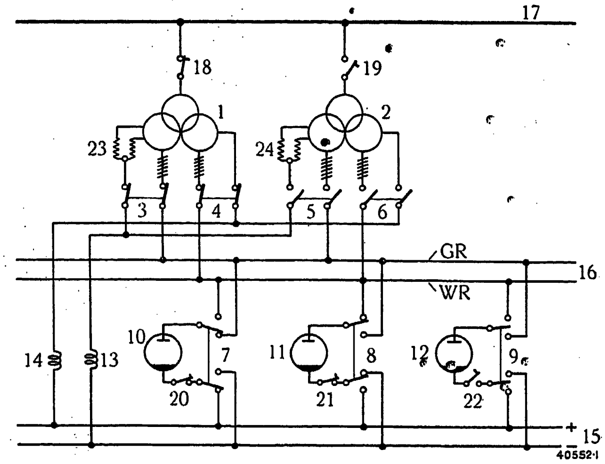


Fig. 53. — Fundamental diagram of connections of main-current circuit in the Van Reenen and Colworth Halt Substations, South Africa.

1, 2. Transformer.
3, 4, 5, 6. Disconnecting links.
7, 8, 9. Mutator change-over switches.
10, 11, 12. Mutators.
13, 14. Choke coils.
15. D. C. system.
16. Aux. bus-bars.
17. Primary 3-phase system.
18, 19. Oil circuit breakers.
20, 21, 22. Quick-acting breakers.
23, 24. Absorption choke coils.

3000 V. Of these three mutators, one will, usually, act as a three-phase D. C. unit and deliver 1500 kW while the second will be used for recuperation, i. e. to convert D. C. into three-phase current. The third unit is a spare.

The two mutators usually in service will be supplied by a common transformer (a second transformer acting as a spare). The high-voltage winding of the transformer is connected up to the 88,000-V three-phase distribution system. Of the two low-volt-

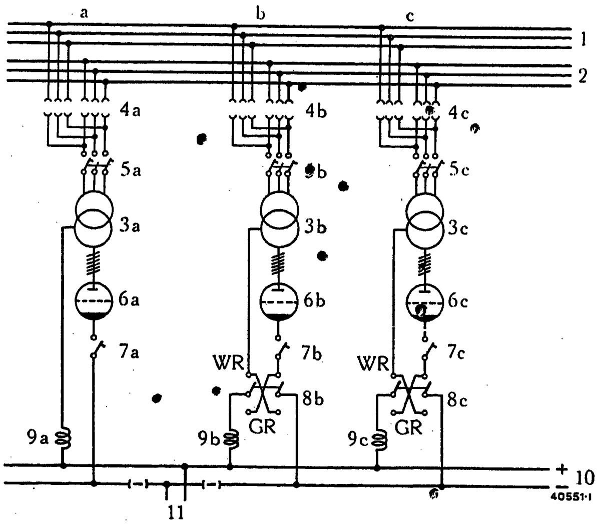


Fig. 54. — Fundamental diagram of connections of main-current circuit in the San Viola-Bologna Substations of the Italian State Railways.

a. A. C.—D. C. mutator set.
b. c. Mutator sets which can be changed over.

1, 2. Three-phase system of various frequencies.
3. Transformer.
4. Disconnecting links.
5. Oil circuit breaker.
6. Mutator.
7. Quick-acting breakers.
8. Change-over switch.
9. Choke coil.
10. D. C. railway system.
11. To feeder breakers.

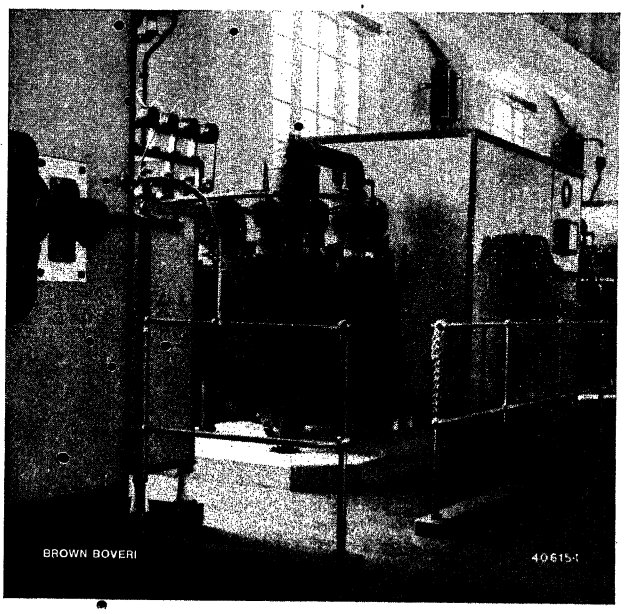


Fig. 55. — San Viola-Bologna Substation of the Italian State Railways.

age windings, one is used for the three-phase D.C. service and the other for the D. C. three-phase service.

Fig. 54 shows the fundamental diagram of connections for the S. Viola-Bologna Substation of the Italian State Railways, with three mutators, two of which can be changed over at will to A. C.—D. C. or D. C.—A. C. service. In the latter service, they can either return D. C. recuperative power to one or other of the three-phase supply systems or elastically couple the two latter through the medium of D. C.

Fig. 55 shows an inside view of a part of this substation. The diagram of Fig. 54 also corresponds in principle, to that of the *Cava dei Tirreni* substation of the *Italian State Railways* which was put into service last year, with the difference that there is only one three-phase supply system, here, and that only one mutator set can be changed over to D.C.—A.C. conversion. The latter switches over automatically under the influence of a power re-

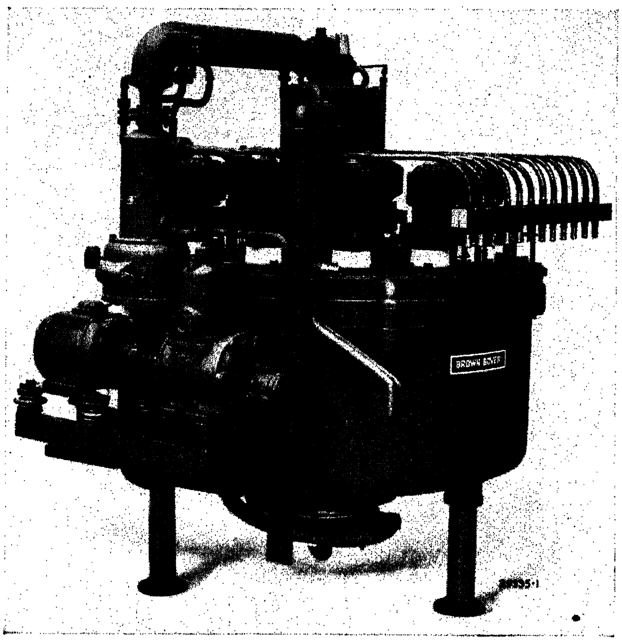


Fig. 56. — Mutator set of a substation of the Italian State Railways, with grid control and built-on ventilating equipment.

lay, when the two A.C.—D.C. mutators are overloaded, and acts as one of them, it goes back, automatically, to D. C.—A. C. mutator service when the load of the said two mutators is down to normal again.

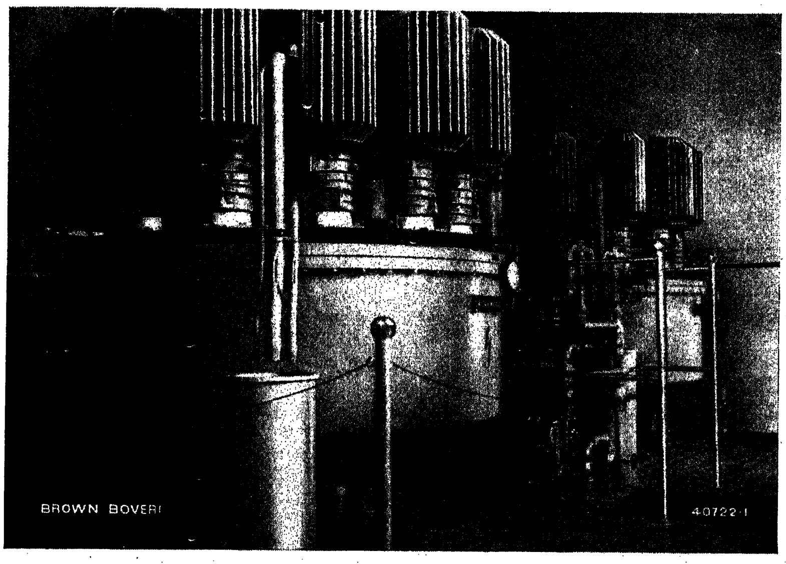


Fig. 57. — Steeg Aluminium Works (Austria). 2 mutators each for 4200 A, 360 V.

Mention should be made, here, of the *Italian State Railway* order placed with us in common with *Tecnomasio Italiano Brown Boveri* for 26 mutators each of 2000 kW and 3000 V D. C. which are placed on the *Incisa, Cortona, Orte* and *Prenestina* substations of the Florence Arezzo-Chiusi-Orte-Rome line section, which is in process of electrification; in the *Sezze, Villa Literno* and *Naples-Poggioreale* substations of the Rome-Aversa-(Naples) line section; in the *Udine, Moggio* and *Comporosso in Valcanale* substations of the Udine-Tarvis line section and in the *Porretta Terme* and *Sasso* substations of the mountain line section Prato-

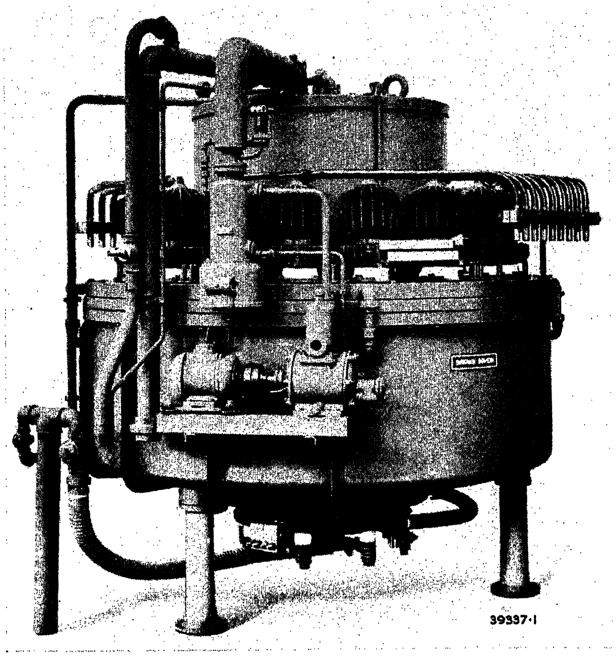


Fig. 58. — Mutator with built-on ventilating equipment and cooling pipes for indirect fresh-water cooling.

Pistoia-Porretta-Bologna to be converted from three-phase to direct current. Over and above these units, there are travelling substations with 8 three-phase-D. C. mutators. Fig. 56 shows the mutators 2000 kW, 3000 V delivered to all the substations mentioned of the Italian State Railways.

The *Southern Railway*, England put up 23 further substations to allow of extending their electrified system to Eastbourne and Sevenoaks; the mutators for these substations were built by our licencees Messrs. *Bruce, Peebles, Edinburgh*, according to data furnished by us, while the automatic gear, vacuum pumps and measuring devices were built by us. A part of the said substations was put to work in the course of last year.

An interesting heavy-current mutator plant for 8330 A—6820 A, 360 V—440 V D. C. was delivered for the electrolysis of aluminium in the *Steeg Aluminium Works* of the *Oesterreichische Kraftwerke* (Austria).

The current of 8330 A is delivered by two mutators which can be regulated (Fig. 57) the primary sides of which are connected up to a common transformer. To allow of continuous regulation of the bath voltage between 100 V and 440 V and, also, as a protection against back fires, both mutators are equipped with controlled grids which are also utilized for starting up the aluminium baths smoothly and for compensating the voltage fluctuations which occur on the three-phase system of the Oesterreichische Kraftwerke. The two mutators which can thus be regulated allow of adjusting the D. C. voltage to all service conditions occurring in such a way that the current is utilized to the best possible advantage and, therefore, that production is maximum.

In order that the power factor should not fall below 0·8, as a result of grid control when the D. C. voltage is brought down, the transformer placed before the mutator is equipped with a regulating winding and on-load step switch having a few wide steps only.

The short-circuit protection combined with the controlled grids, the grid relay and ignition distributor allow of clearing all short circuits within 1—2 hundredths part of a second, without lowering production or stressing unduly the A. C. or D. C. apparatus involved in the short circuit.

Mention can, also, be made of the delivery of mutators for high D. C. voltages to supply transmitting valves, these being a set of 750 kW at 20 kV for the *Motala wireless transmitting station* of the *Royal Swedish Postal Administration*, a set for 600 kW, 20 kV for the *Roumanian transmitting station in Brasov*, a 300-kW set 13 kV for the *Lambergseter transmitting station* of the *Norwegian Telegraph Administration* and a 750-kW set 18 to 20 kV for the *Lahti transmission station in Finnland*. The increase of the valve voltage of the *National Swiss Transmitting Station* at *Beromunster* from 12 kV to 20 kV was the occasion for the installing of a mutator set 450 kW, 20 kV. Our new protective equipment with surge transformers for protecting transmitting valves was used here for the first time.

Fig. 58 shows a mutator of 2500 kW, 520 V, 4800 A to supply a rolling-mill drive. This service entails periodically recurring and very high overloads

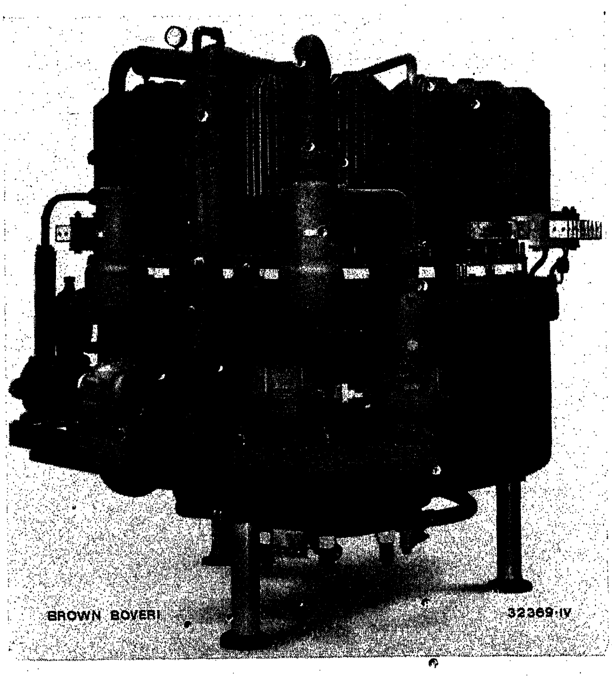


Fig. 59. — Mutator, 5000 kW, 590 V, 8500 A, showing cooling pipes and air-pump sets.

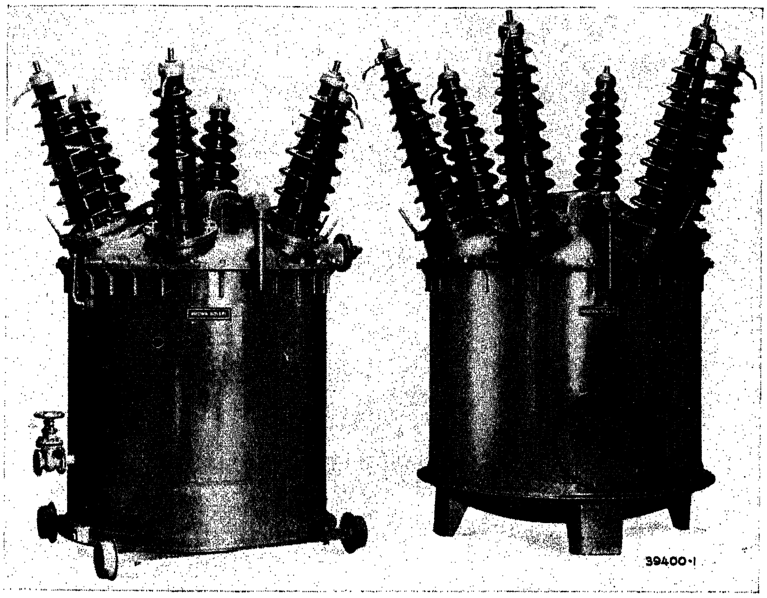


Fig. 60. — Left: Three-pole oil-circuit breaker Type OKF 18 i 3, with convectors, for outdoor erection, rated voltage 87 kV, rated current 400 A, rupturing capacity 750 MVA. Right: Three-pole oil-circuit breaker Type OKF 22 i, with convectors, for outdoor erection, rated voltage 110 kV, rated current 400 A, rupturing capacity 1000 MVA.

of 100% lasting one minute, reappearing every ten minutes and overloads of 50% lasting 5 minutes recurring every fifteen minutes.

(9) *Apparatus.*

Uniform and systematic progress has been made in the development programme laid down at the beginning of last year and covering every type of circuit breaker built by us and using oil, water and air as an extinguishing medium.

To begin with, the convectors, which gave such satisfactory results when used with our circuit breakers with small oil filling, were introduced into the design of *single-tank three-pole oil circuit breakers* for 87 and 110 kV (Fig. 60). It can be asserted that the convector, with the small volume of gas it generates, alone made it possible to build three-pole single-tank breakers for voltages as high as these while keeping the dimensions within reasonable limits. Earlier types of single-tank breakers for such high voltages did not meet this last condition and could not hold their own against sets of three single-pole breakers. The rapid rupturing time as shown in the oscillogram of Fig. 61, is a remarkable feature of the new single-tank circuit breaker.

The design of the *compressed air circuit breaker* 50 kV has been altered (Fig. 62). Compressed air is not used as an arc-extinguishing medium only, but to close and open the breaker. As shown in Fig. 62, the air cylinders are secured to the three upper supporting insulators; the pistons of the said cylinders are connected to the moving part of the extinguishing contacts. Above, are placed the ring-shaped stationary contacts and the cooler. Before the breaker

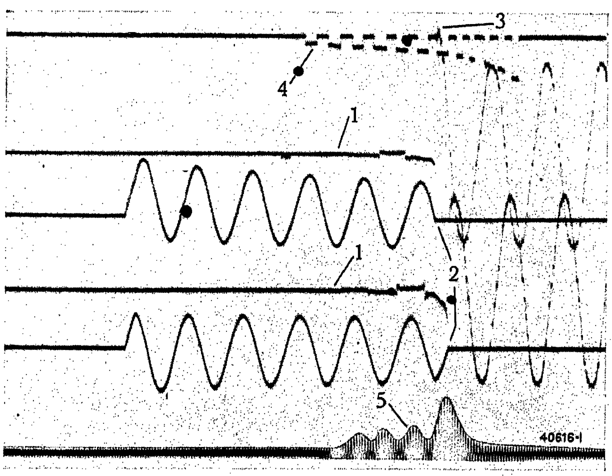


Fig. 61. — Rupturing oscillogram recorded on one of the three-pole single-tank breakers shown in Fig. 60.

1. Beginning of rupture.
2. End of rupture.
3. Recovery voltage over first extinguished phase equal to 1.5 phase voltage.
4. Contact movement.
5. Pressure curve in a convector.

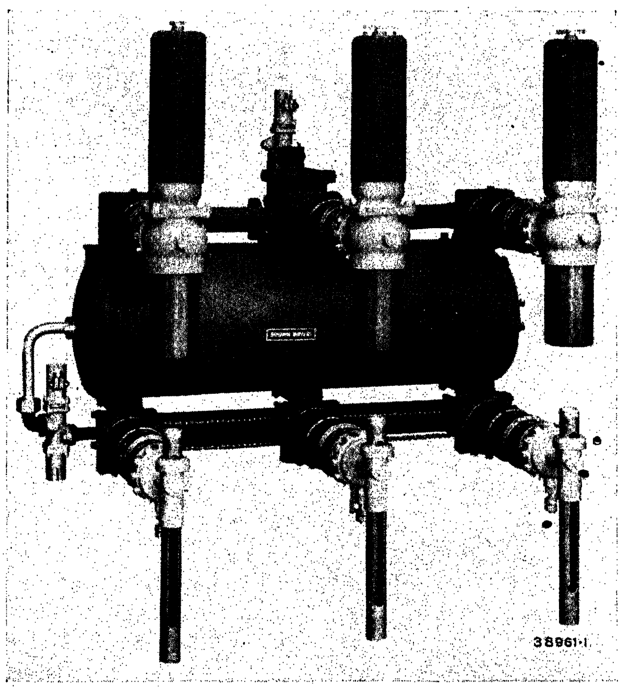


Fig. 62. — Three-pole compressed-air circuit breaker with compressed-air container, breaker open, rated voltage 50 kV, rated current 640 A, rupturing capacity 400 MVA.

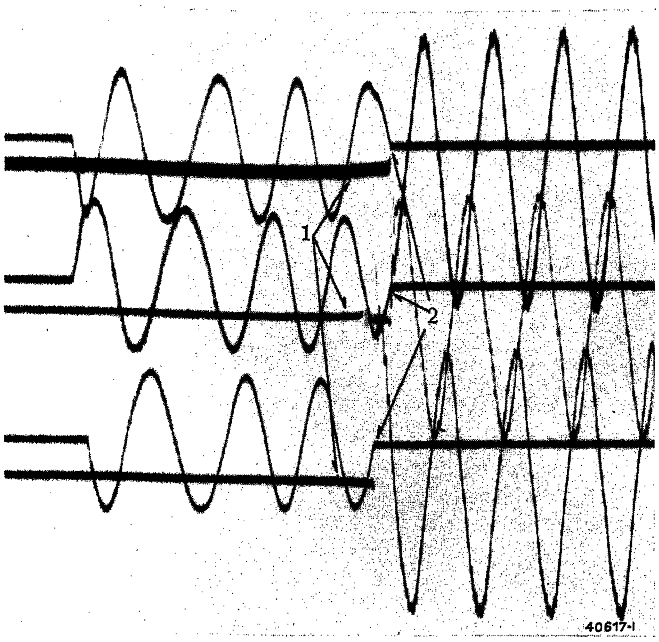


Fig. 63. — **Rupturing oscillogram on three poles recorded on breaker 50 kV shown in Fig. 62.**

Average rupturing current 6010 A (R. M. S.) Composed recovery voltage 48,500 V. Rupturing capacity 504 MVA. Max. duration of arc 1·2 half cycles.

1. Initiation of rupture. 2. End of rupture.

is closed, the extinguishing contacts are already closed while a disconnecting link in series with them is opened. At closing the breaker, the latter is closed by compressed air. The moving part of this link and its guiding organs are held by the lower supporting insulators. When the breaker opens the extinguishing contacts are separated, also by pneumatic force, during which operation compressed air streams out to the outer air through the hollow fixed contacts and the cooler. The rupturing arc is cooled in this manner and extinguished. After the rupture, the disconnecting link in series is opened and then the extinguishing contacts are closed again. The compressed air to operate the breaker is taken from a container built on to the breaker. The oscillogram of Fig. 63 shows an arc ruptured by this breaker.

The illustration on the cover of this number shows a set of convector circuit breakers in the *Chèvres outdoor station* of the Service de l'Electricité de la Ville de Genève. Fig. 64 shows the whole plant and Fig. 65 a variety of water circuit breakers, built for 11 kV rated voltage and 250 MVA rupturing capacity, mounted in the *Monbijou Substation* of the *E. W. der Stadt Bern.*

In parallel with the changes made in circuit-breaker design, the accessories belonging thereto underwent considerable developments. In the first place, we would mention a *new definite time series relay.* This is an evolution of our classic time relay Type H 4, which was first shown in 1914 at the National Exhibition in Berne and of which 50,000 have been put to work with the most satisfactory results. The requirements of recent years, however, based on recent electrical developments, have made necessary a new design of this excellent relay.

Fig. 66 shows the new series relay type HB 4. Its main organs are the magnet with current coil, the time mechanism and the tripping device. A small synchronous motor, which is held stationary during the normal course of service, is located in the magnetic circuit. When the pick-up current, to which the relay is adjusted, is exceeded, the armature of the magnet is drawn forward through a short distance, the time gear is pulled into mesh and the stop holding the motor removed. The time gear starts to run and, at the end of the time lag to which it is set, it frees a catch so that the armature of the magnet can be completely drawn up. At the end of its travel, the armature causes the tripping rod to receive a sharp blow through the agency of the tripping lever.

The relay can be set for tripping instantaneously or after a time lag of 0·3 to 6 seconds. In the latter case, instantaneous tripping is also obtainable by means of the so-called limit-current setting; in which case the relay trips instantaneously when the limit current, which may be adjusted between the limits of 3 to 6 times the rated current, is exceeded. The same

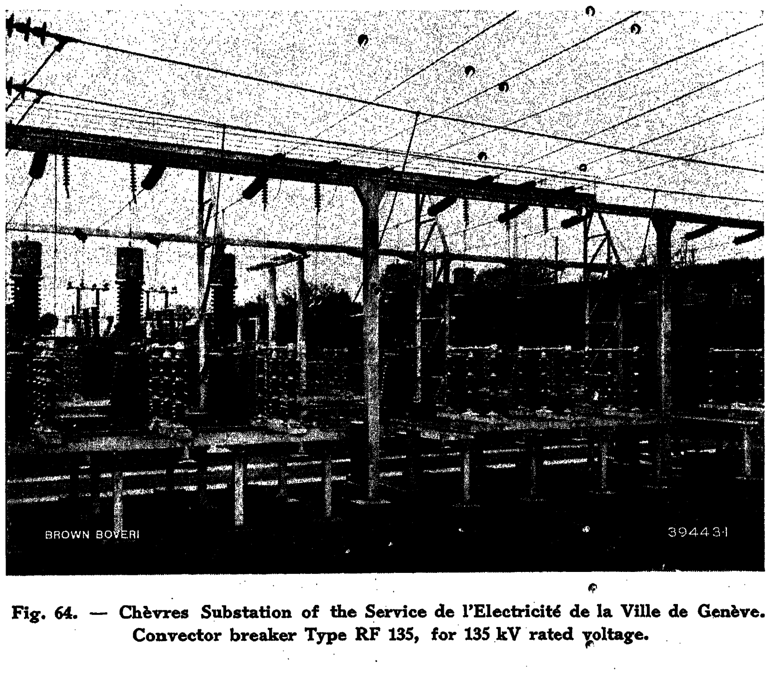


Fig. 64. — **Chèvres Substation of the Service de l'Electricité de la Ville de Genève. Convector breaker Type RF 135, for 135 kV rated voltage.**

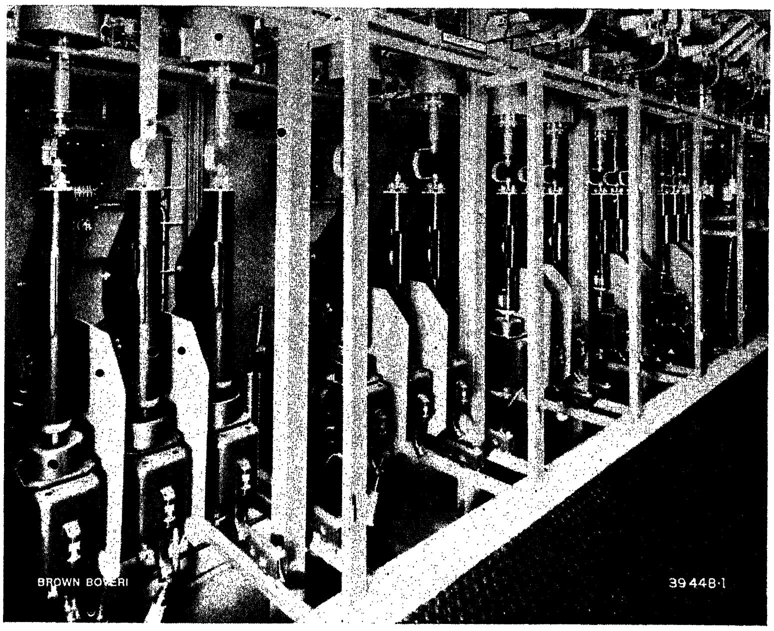


Fig. 65. — Water-circuit breaker Type U 11 i 250, for 11 kV, 250 MVA, with compressed air drive. Bushing type current transformer, placed above the breaker; Monbijou Substation of the E. W. der Stadt Bern.

setting organ allows the blocking of all instantaneous tripping. The time-setting mechanism is lodged in a housing and well protected against dust. The housing carries the scale plate on its front side, which scale gives the characteristic data of the relay, it also carries the two scales for setting the time lag and the pick-up current, the pointers a and b of which can be displaced by means of a setting rod, if the setting of a and b is not locked by devices provided for that purpose. On the right of the housing is the lever c for adjusting the limit current, the strength of the latter current can be read off a scale on the setting lever c as a multiple of the rated current.

For rated currents up to 60 A, a protecting resistor is connected in parallel with the current coil f to prevent flash overs on the relay when voltage surges occur. In order to ascertain immediately after the tripping which phase was overloaded when built-on series relays have operated, the relays can be provided with drop disc indicators. After the relay has tripped, these discs can be put back in their service position by the setting rod.

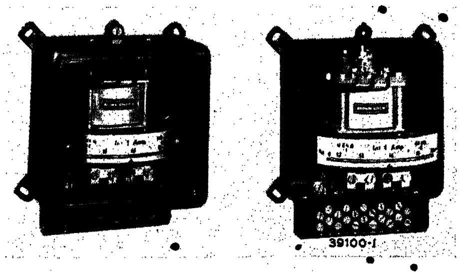


Fig. 67. — Maximum-current relay of small power consumption for connecting up to current transformers.

For cases where the imperviousness of the relay HB 4 to short circuits does not suffice, it is designed with a power storage device (spring) and termed type HK 4; the expansion of this spring causes the breaker to trip. The relay has only to furnish the work required to actuate a tripping catch which frees the power stored. The spring is compressed again, automatically by the driving mechanism of the breaker, through the releasing rod, after it has been tripped.

Up to a rated current of 30 A, the current coil of this relay also has a protective resistor in parallel with it.

The new relays for direct tripping (Type HB 4) are built for current ratings of 8—1200 A and for power-storage tripping (Type HK 4) for current ratings of 4—600 A, with a setting range of the tripping current of 1·2 to 2 times the rated current.

The great precision of this relay as regards time lag-setting (margin $\pm$ 0·1 sec) allows of stepping the time lags at 0·5 sec between two relays placed one behind the other, if the opening times of the circuit breakers themselves on the line are lower than 0·2 sec. Further the time lag of the most remote relay on a branch line can be adjusted to instantaneous tripping, as compared to one second which was the lowest setting on the old relays. The possibility of such short time settings is also advantageous for branch lines connected up to systems which are equipped with distance relays.

The coils of the relays are so dimensioned that in the case of Type HB 4 they can carry a current 125 times greater than the rated current for one second without getting too hot, this figure being 250 for Type HK 4. The relays can also withstand sudden short-circuit surges of 500 and 1000 times their rated currents

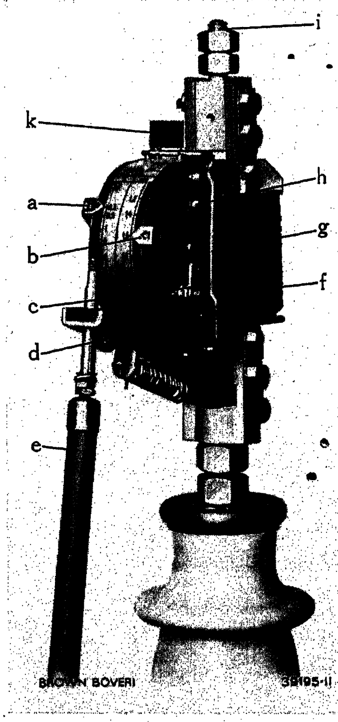


Fig. 66. — Series relay Type HB 4.

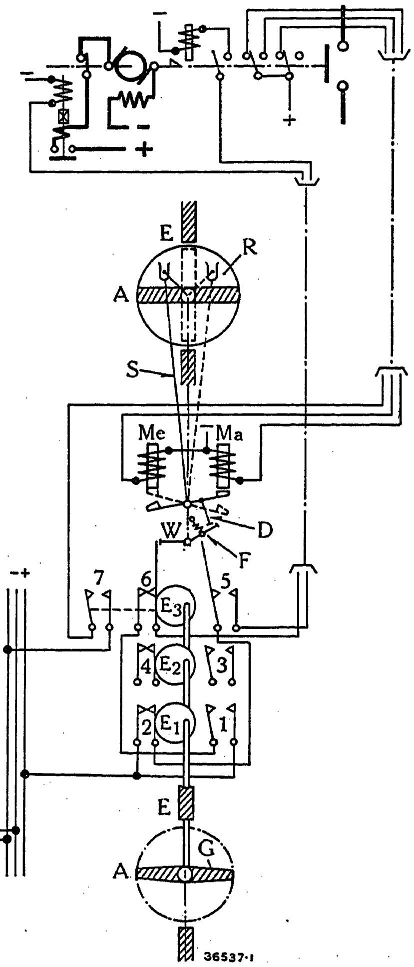


Fig. 68. — Fundamental diagram of connections of control switch Type L for indirect operation of remote control drive of circuit breakers.

respectively up to a maximum of 100,000A. The high mechanical stressing which results from such surges is withstood by the relays thanks to their design with sprung catch device, etc.

Fig. 67 shows a new *over current relay for instantaneous tripping* characterized by the little power it consumes and used chiefly as a secondary relay to be connected to bushing-type current transformers of low output, or as a differential relay. It is composed of a rotary system which actuates a change-over contact for low rupturing capacity. In order to introduce a time lag element the relay can be provided with a built-on intermediate relay with a time lag of 0·2 sec or it can be connected to a separate time relay.

Under the designation of *control switch Type L* we have brought out a control switch for indirect operation of the remote control drive of circuit breakers, which combines the selective switch and position indicator in a single apparatus. As shown in Fig. 68, three excentrics E_1, E_2 and E_3 are rigidly connected to the shaft of the control handle. The position-indicator disc R is controlled by the armature of the position indicator magnets M_e and M_a, through a rod S. There is no mechanical connection between the excentric shaft and the position indicator. The disc of the position indicator carries a red mark of the same width as the stripes on the position indicator diagram.

The position of the handle marks the last order imparted while the position indicator corresponds to the position of the circuit breaker controlled; the "In" and "Out" positions are displaced by 90° from one another.

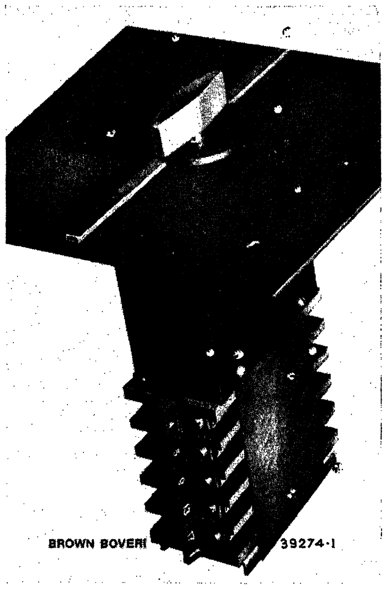


Fig. 69. — Control switch with signalling device, rated voltage 660 V, rated current 10 A.

The fundamental diagram of connections of Fig. 68 shows clearly that the current circuits for the "In" and "Out" impulses have each got two contacts connected up in series (namely 1 with 6 and 2 with 5). Contacts 1 and 2 are controlled by excentric E_1 alone. The contacts 5 and 6 in series with the others are closed by excentric E_3; the position indicator, on the other hand, permits the "Open" order to be carried out.

Fig. 68 shows the control handle and position indicator in the "Out" position; their position thus coincides with that of the circuit breaker. To close the latter, the control handle A is rotated to the E position. This results in contacts 1 and 5 being closed and contact 2 opened. Contact 6 in series with contact 1 is interlocked by rocker W and cannot open for the moment, even if excentric E_3 sets it free to do so. The circuit breaker drive gets its closing impulse, now, through contacts 1 and 6. As soon as this order has been carried out, magnet M_a is deprived of current while mag-

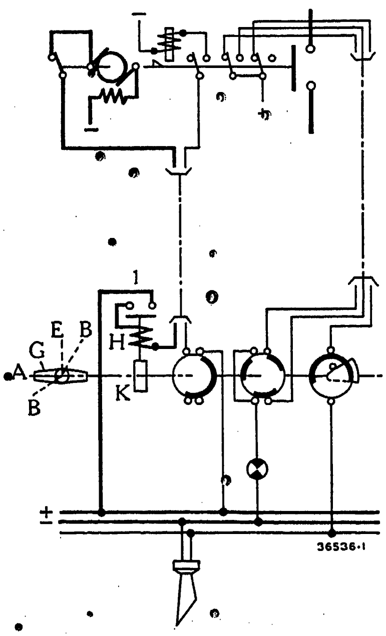


Fig. 70. — Fundamental diagram of connections of selective switch Type K for direct control of circuit breakers (motor power storage and solenoid drives).

net M_e is excited. This causes the position of the rocker W to be altered through action of stud D connected to the armature, which frees contact 6 and interlocks contact 5. By altering the position of rocker W, spring F is stretched.

Simultaneously, with the opening of contact 6 the alarm contact 7 is closed and the signalling of an automatic circuit breaker tripping is prepared. If tripping of the breaker has taken place, the alarm contact can be opened by drawing back the control handle (signal acknowledged). Hunting is prevented by contact 6. As there is an interlocked contact 5 in the "Out" current circuit, as well, the circuit breaker drive can be controlled from two positions, without the impulses imparted by the control switch cancelling one another.

Opening the circuit breaker is effected over contacts 2 and 5 and is easy to unterstand as it is similar in process to the closing operation just described.

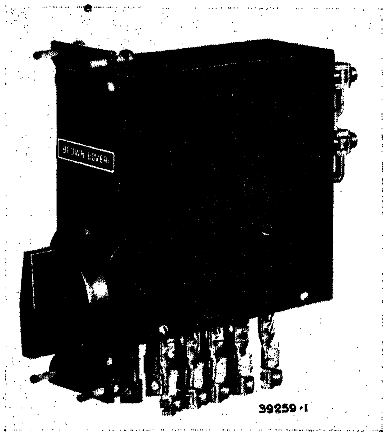


Fig 71. — Selective switch with holding magnet, rated voltage 660 V, highest switching-in current 150 A.

In practice, the excentrics E_1, E_2 and E_3 are designed to form an excentric drum. The position-indicating disc is placed just behind the control handle and is concentric to the latter. In the "acknowledged" positions (control switch "In" and circuit breaker "In" as well as control switch "Out" and circuit breaker "Out") the control handle covers the indicating mark on the position indicator. If both position indicating coils are dead the position indicator goes into a position at 45° (sign of trouble when a line is cut out or if the auxiliary voltage has failed).

Fig. 69 shows a view of the control switch.

An interesting newly-designed *selective switch* has been put on the market for the control of circuit breakers (motor-power storage and solenoid drives). Fig. 70 shows the fundamental diagram of connections of this switch.

To signal the last control order imparted, the selective switch has two positions at 90° from one another, namely:— An "Out" and an "In" position. The momentary giving of an order is carried out by rotating the handle G by 30°, beyond the usual "Out" and "In" position and into the so-called "Order" position. When left to itself, the handle goes back to the corresponding ordinary position.

The handle G holds in the given position, on account of its carrying a contact device with holding coil H along with it through a coupling K. In the position "In order", this coil H closes the circuit of the driving motor. After the closing of contact 1 the coupling K is released the contact being held closed by the holding magnet alone, as long as the holding coil is alive, this even if the handle is brought back to the "Out" position too soon or if it is freed too soon. If the current is broken, the contact is opened even if the handle is held for any length of time in the "In" order position (prevention of hunting).

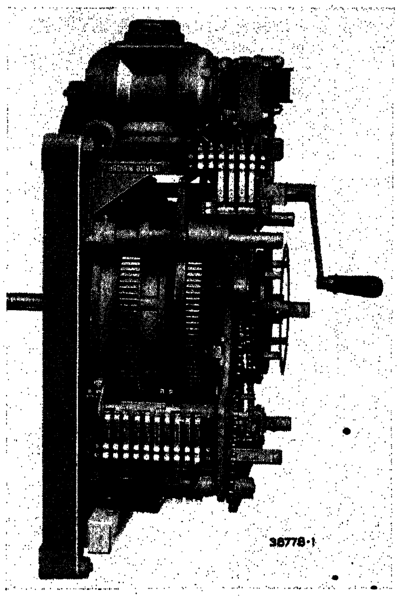


Fig. 72. — Power-storage drive for step switches.

The contact drum has three switches independent of each other, one of which controls the switching out, the second the position indication and the third the alarm signal.

A single position indicating lamp suffices which lights up in the following position:—

Control handle in	"In-order", position,	breaker in	
" " "	"Out-order" "	"	out
" " "	"In" position	"	out
" " "	"Out" position	"	in

In the "order" position, the lamp shows that the orders have been carried out and in the rest positions of the selective switch it shows each difference of position that is to say it indicates an automatic circuit break or closing of the breaker by hand or by another control switch in parallel.

Two lamps can be used for position indication one of which is always in circuit. It is, however, recommendable to use one lamp only.

The alarm contact is so made that it is only closed during the return movement of the control handle from the "In-order" position to the "In" position. In this way the alarm is prevented from acting when the breaker is closed. When the circuit breaker trips

automatically the alarm contact can be opened by rotating the control handle to "Out".

Fig. 71 shows the design of the selective switch type K; only the control handle with the indicating ring with position marks is mounted in front of the control panel. The selective switch is easy to mount in switchboards or desk panels by means of four screws.

Experience showed the desirability of actuating *step switches* of regulating transformers by *power-storage drives,* so that a given switching operation may be carried out and completed if the voltage of the driving motor should fail, for any reason. This is attained by causing the driving motor to load a spiral spring instead of acting directly on the shaft of the step switch. When the spring is loaded, the motor is cut out and the spring liberated. The spring, on distending, drives the step switch one step further. The switch shown in Fig. 72 works in the following way:— if the selective switch which controls the step switch is actuated, the motor of the power-storage drive is switched in for the correct sense of rotation through the agency of a switch magnet. The torque of the motor is transmitted through a reduction gear to a rim of teeth. The latter rotates according to the sense of regulation, in clockwise sense, for example. In doing so the external extremity of the spring is carried along with it while the internal extremity of the spring and a disc keyed to the driving shaft is maintained stationary by a catch along with the shaft. After the spring has been wound up by 360° the driving motor is cut out and the aforementioned catch is released. The inner extremity of the spring can now follow up and carries the disc with it. After rotating through a small angle, a raising segment which has held the brake open is over run and the brake which has been held raised comes into action and stops the motor. After rotating through 360° the disc is stopped by the catch; the step switch has moved over one step. The raising segment mentioned before acts on the brake again and releases it. In order to overcome torque peaks on the step switch the drive has a flywheel driven through a slip coupling. In order to make the step switch work in the other sense, the driving motor is switched in for rotation in the opposite sense by a second switch magnet. The rim of teeth rotates in counter-clockwise sense and, this time, the interior spring extremity is carried along, first. The switch magnets for the two senses of rotation are so interlocked with each other, mechanically and electrically, that the one can only switch in when the other is switched out. When the step switch has reached its end position an end-travel switch on the drive is actuated which breaks the current circuit for that sense of rotation. It is, then, only possible to actuate the step switch in the opposite sense of displacement. The drive is also equipped with a prevention device with protective contact which closes the tripping current circuits of the breakers placed before and after the transformer, if, for some reason, the step switch has not been able to attain one of its normal positions within the space of time adjusted to on the prevention device. This prevents damage being done to the step resistances which are calculated for short loading periods.

For automatically controlled regulating plants, another preventive device with contact is provided through which the circuit of the switch magnets is led. If the step switch begins to move the contact opens. When the step switch is again in a normal position the contact closes after a given time lag. This prevents over-regulation, i. e. the control relay has time to get back to the rest position.

The power-storage drive is provided with a disc carrying figures to mark the positions. For remote signalling of the positions, an electro-dynamical indicating apparatus is usually used driven by chain; this controls the indicating (receiver) instrument at the spot where readings are desired.

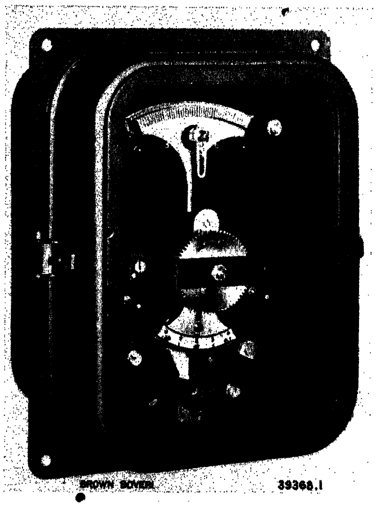


Fig. 73. — Quick-acting regulator, Type J 1/1, voltage regulator for A. C., rated voltage 250 V.

For purposes of signalling and interlocking the power-storage drive has auxiliary contact drums driven by chain.

Finally, we have met the demand for a *small,* cheap *A. C. quick-acting regulator* by bringing out a new type based on the single-sector principle (Fig. 73), which is intended for those plants which do not require the high degree of precision associated with our Type AB and where the question of cost is the chief factor. The new design is similar to that of Type AB, but the overall dimensions are considerably smaller as the regulating load is lower.

The magnetic circuit system is composed of four magnets of laminated iron between the poles of which an aluminium disc, mounted on the regulating shaft, can rotate. The field of the magnet is created by a ring shaped coil which encloses the aluminium disc concentrically. The coil is supplied by the voltage

to be regulated. Each magnet has a short-circuited winding. According to the Ferraris principle, the disc is subjected to a torque proportional to the square of the voltage applied.

The main spring and the auxiliary spring which produce the counter torque are similarly designed to those of quick acting regulator Type AB. The main spring is in a housing, the rotation of which alters the spring tension. To this end, the flat spring and peg which penetrate the smooth cover of the housing are pressed outwards, the housing rotated by hand and the flat spring pressed in again. The auxiliary spring can be more or less tightened by displacement of the screw which is a fixed regulating point.

The shaft of the motive system is carried by spring stone bearings. Dismantling the motive system does not necessitate touching the screws of the stone bearings, so that, when the motive system is replaced it lies true on its bearings. There are two spring stops to prevent the motive system moving through more than 60°. There is a woven resistance in series with the coil which is held by supporting bolts at the back of the supporting plate. Tapping terminals allow of fixing the resistance correctly before the regulator leaves the shops.

The new quick-acting regulator has *one* contact sector only and *one* contact track with 50 steps. The individual contact sectors are prolonged on the rear side and designed as loops between which the resistances are stretched. The contact sectors are silver-plated and the contact sector has a heavily silver-plated streak along its rolling track.

As with regulator Type AB, the damping device is composed of two permanent magnets between the poles of which an aluminium disc rotates. This is flexibly coupled to the motive system through the damping sector and recall spring. The latter is a double flat spring. Its effect can be altered by displacing its point of action on the damping sector.

(10) *Switchgear.*

The design of switchgear plants has been considerably influenced by the new types of apparatus now in use, such as water circuit breakers, convector and compressed-air circuit breakers. This new apparatus did not influence the appearance of the switchgear plant as a whole, but it permitted of advantageous alterations in the layout of leads and connections. The illustration on the cover of this number shows the erection of 135-kV convector circuit, breakers in an outdoor station. The current transformers, of high measurement precision, which in older plants were lodged in separate frameworks, are, here, built into the lower part of the breakers themselves. This is a saving of space and makes supervision easier. In the present example the convector circuit breakers are mounted on high frameworks to prevent either operators or visitors coming into contact with parts under voltage.

In other plants, the same breakers are placed on low supports, which has the advantage of making all parts of the apparatus accessible to the personal of the station; this layout facilitates inspection, small repairs and the changing of separate parts or of whole breakers. The breakers, however, must be isolated by railings or screened off from the rest of the plant to prevent accidental contact with parts under voltage.

When water circuit breakers are used, the straight vertical layout of the leads, characteristic of this type of breaker, is generally adopted. That is to say the leads are carried from the bus-bars to the disconnecting links from thence to the water circuit breakers and then to the cable-end boxes, as shown in Fig. 65. Fig. 65, also, shows the introduction of compressed air to operate the circuit breakers, which is an innovation. Compressed air has given excellent results in recent practice, as a universal means of control for circuit breakers, disconnecting links, and a variety of electric appliances used with windows, doors, valves, etc. and, more especially, for power storage drives. By careful planning and suitable installation of the compressed-air plant proper and of the distribution pipes the same degree of reliability is attained as when electric drive by batteries is resorted to. As regards the design of oil circuit breakers, the following trend of design has developed:— our

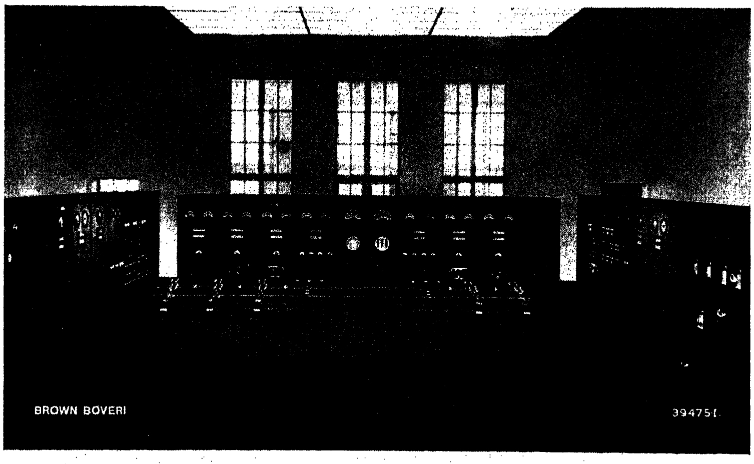


Fig. 74. — Centralschweizerische Kraftwerke Luzern. Control room of the Unteraa Power Station, desk-type switchboard having deeply engraved coloured signalling diagram. Instrument board placed behind it, for the outgoing lines and the station requirements (D. C. and A. C.), for 2 generators 4000 kVA, 1 generator, 12,000 kVA and 2 generators 18,500 kVA, as well as for 2 incoming lines 8800 and 3400 kVA, respectively, 8000 volts, 50 cycles and 5 outgoing lines for 50 kV, 50 cycles.

oil circuit breakers are being placed in the open or in simply designed cells instead of in explosion-proof chambers as was the case up till a few years ago. The reason is that oil circuit breaker-explosions practically never take place, to-day, thanks to exact calculation and proper dimensioning of the said breakers, for which the tests carried out in modern high-power testing plants gave the necessary data.

As regards control room layout and switchboard design, increasing importance is being attached to remote control and position-signalling apparatus.

Control-switch Type L, already described in this article, has given excellent results, here. Figs. 68 and 69 show the layout of these switches both as position-indicating switches for the control of the main circuit breakers and as control room position indicators for disconnecting links.

A complete switchgear plant, for which we booked the order last year and which should be mentioned here is that of the *Pallivasaal Power Station, India,* which includes five remote-controlled single-tank oil circuit breakers for 66 kV, the control room equipment including a mimic board and the whole auxiliary service plant. The two eight-pole three-phase generators of the power station, for 5000 kVA, 11,000 V, 50 cycles as well as the two three-phase, three-winding transformers of the same output, for 66 kV on the high-voltage side are also being delivered by us.

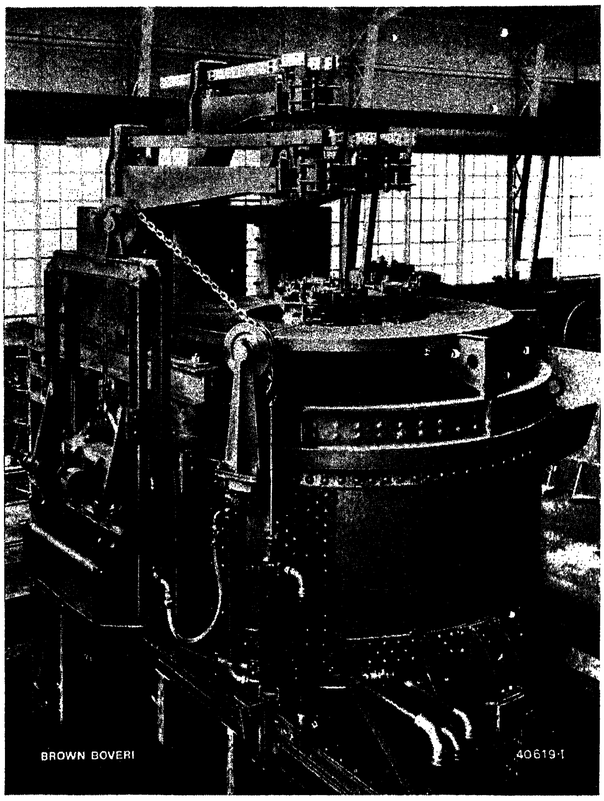


Fig. 75. — Electric arc furnace with a hearth body which can be run in and out so that it can be grab-charged. View taken during erection.

(11) *Electric furnaces.*

Despite the severe industrial crisis, we succeeded in placing a large number of our electric furnaces of every type in the course of last year. One of the reasons for this is the recognition by the power supply companies of the importance of the electric furnace as a power consumer to balance the falling-off in the power consumed by big industries etc. This trend is the correct one and has been furthered by advantageous metering terms granted to furnace owners. Another advantage of the furnace is the even power consumption it works under and the fact that it, practically, takes no wattless load, thus influencing the voltage conditions of the system favorably. By encouraging the use of electric furnaces, it may be possible to bring up the output of the power stations to full load again, thus opening the way to their further development and enlargement.

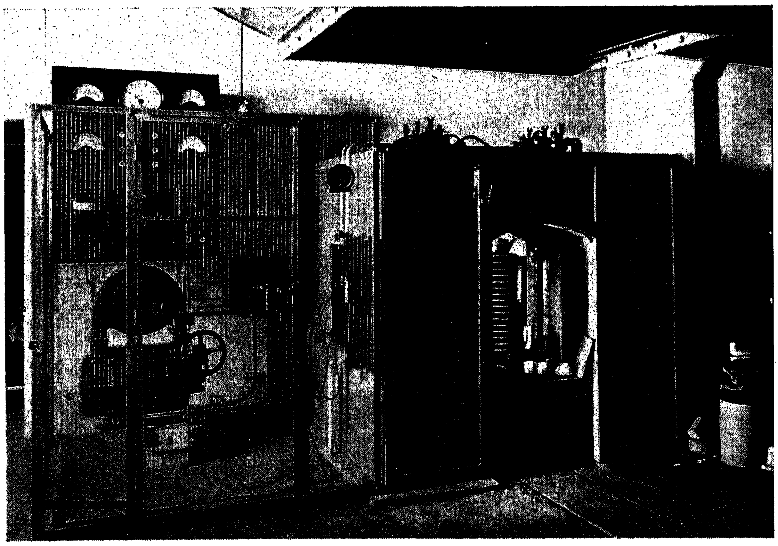


Fig. 76. — Electric furnace for firing porcelain. Highest furnace temperature 1400° C. dimensions of the furnace muffle 550 × 680 × 600 mm, power intake 35 kW, for the Schweizerische Porzellanfabrik Langenthal.

The biggest steel furnace with electro-hydraulic electrode control of our well-known design built up to date has a charging capacity of 25 t. Fig. 75 shows a melting furnace of 7·3 t charging capacity of our latest design with a hearth body, which can be run in and out, so that it can be grab-charged.

Fig. 76 shows a firing furnace, mentioned here last year, for earthenware

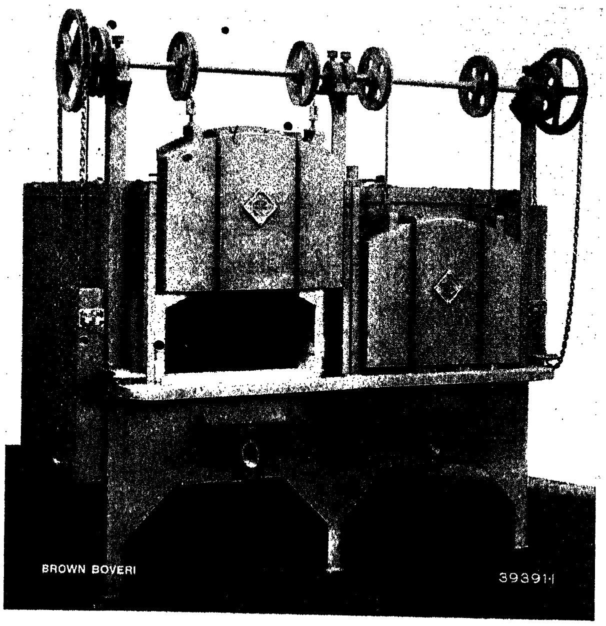


Fig. 77. — Electric-resistance furnace with 2 chambers for melting down old bearing linings and for preheating bearing brasses, dimensions of each heating chamber 1000 × 600 × 300 mm. Input per chamber 10 kW.

goods and for a maximum temperature of 1400° C, input 35 kW. The proper firing of eathenware goods, fire-clay ware and porcelains in electric furnaces can be considered as a problem which has been satisfactorily solved in every respect. The studies carried out on the problem of firing high grade porcelain wares in electric furnaces have been brought to a successful conclusion and open up an electro-thermic field of great possibilities.

The two-chamber furnace shown in Fig. 77 for melting down old bearing linings is a novel application of this type of furnace.

(12) *Electric traction.*

There have been some further developments made in this interesting field.

As far as the *Swiss Federal Railways* are concerned new developments are limited to the work carried out on new light motor coaches of axle arrangement 2-B_o mentioned here last year. Apart from the new system of air heating described at the end of this article, the coaches have been equipped experimentally with a new type of individual axle drive in which the springs transmitting the torque from the big gear wheel to the driving wheel, lodged in guide casings are built directly on to the said big gear wheel (Fig. 78). The greatest advantage of the drive — which has the wished for result of eliminating the nose-suspended motor from the modern type of high-speed motor coach — is that the spring cups in the wheel casing are shielded from outside influences and that those parts subject to wear are continually being lubricated. Further, the springs are placed round a small diameter directly under the running surface of the gear wheel, being secured to the stationary hollow shaft.

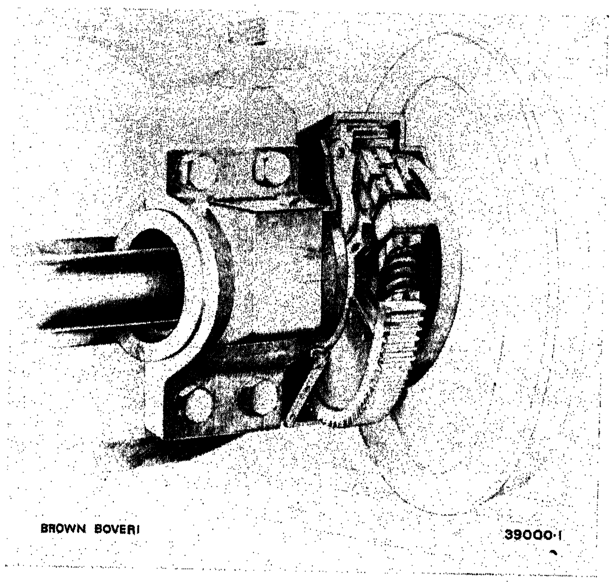


Fig. 78. — Individual axle drive for electric vehicles. Showing hollow shaft secured to driving motor housing, gear drive and spring coupling.

Owing to the poor traffic returns, it seems unlikely that the Swiss Federal Railways will be ordering more electric motor vehicles for the present, unless it is decided to electrify the Brunig Pass line in accordance with the proposal of the Swiss Federal Railways, namely, without altering the permanent way and retaining the present narrow gauge, a solution much preferable to others put forward by various local bodies.[1]

[1] The following electrification work coming within the scope of the second programme of Electrification was carried out in the following sequence, last year:—

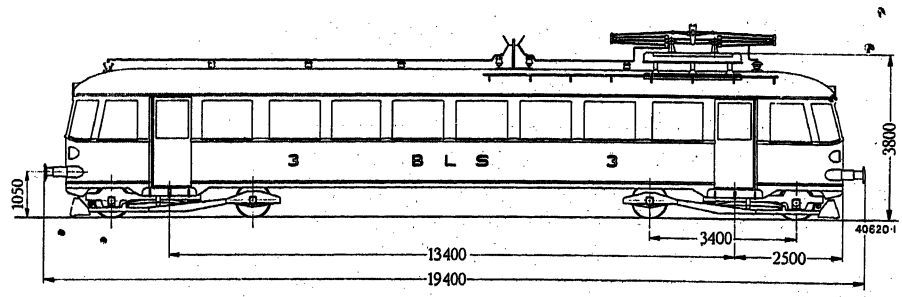


Fig. 79. — Light motor coaches 1 A-A 1 of the Berner Alpenbahn-Gesellschaft, Berne-Lötschberg-Simplon.

In this connection it is worth mentioning that the locomotive No. 11801 of axle arrangement $1B_o\ 1B_o\ 1 + 1B_o\ 1B_o\ 1$ on which, with the twin machine No. 11851, high-voltage control was used for the first time, has now run for 400,000 km and given an excellent account of itself.

The *Berner Alpenbahn Gesellschaft* (Berne-Lötschberg-Simplon) in Berne, has now decided to add light motor coaches to the locomotives they already possess. We received the order for one of these machines, as general contractors (Fig. 79). The net weight of this coach is 26·5 t of which about 9 t is required for the electrical equipment. The length of the coach is 19,500 mm over buffers and it carries 70 passengers seated and 45 standing. The coach body is of light design carried on two two-axle bogies, each of which carries a driving motor. The total motor output at one-hour rating is 250 H. P. corresponding to 60 km/h at which speed the steep gradient of 27 ‰ must be negotiated. The maximum speed is 90 km/h. A cam-type controller remote controlled and connected to the transformer serves as control organ. On down grades, electric braking is resorted to, in which case the driving motors work as separately-excited D. C. generators, over resistances and according to a system of connections used by us for the first time on the locomotives of C. C. Type, Series 401 of the Rhetic Railway, which has proved very satisfactory. The coach is built for one-man control and, for this reason, equipped with our safety device. The mechanical part of the coach was delivered by the Schweizerische Industriegesellschaft, Neuhausen (Switzerland).

The B.L.S. also decided to transform the three motor coaches delivered in 1910 for the Spiez-Frutigen line section. We have received the order for the transformers and for half the motors for this equipment. The power of the coaches will be increased by 80% when the changes in question are carried out.

Our concessionary companies built some interesting locomotives and motor coaches in the course of last year among which we would mention the following:—

Line section Bienne-Sonceboz (14.155 km), Rorschach-St. Margrethen (11.221 km), Sonceboz-La Chaux-de-Fonds (27.887 km), Gümligen-Fluhmühle (83.717 km) and St. Margrethen-Buchs (37.951 km). Thus, at the end of 1934, there were 2058.222 km of line section electrified on the Swiss Federal Railway system, or 73% of the whole full-gauge system, measuring 2868 km.

For *the Italian State Railways, the Tecnomasio Italiano Brown Boveri* built six D.C. locomotives according to the design of the said railway administration. These are for 3000 V contact-wire voltage and of axle arrangement B_o-B_o-B_o of group E 626. This brings the number of locomotives built by Tecnomasio up to 36.

The *Oesterreichische Brown Boveri Werke A.-G.*, in *Vienna* are to build to the order of the *Austrian State Railways* and in collaboration with another firm, the electrical equipment of a B_o-B_o locomotive (single-phase A. C., 15,000 V, $16^2/_3$ cycles, Series 1170—2000). The same firms are to deliver the electric equipment of a four-axle goods motor coach B_o-B_o with a one-hour motor rating of 4×200 kW at 1128 r. p. m., weight ready for service 63 t of which 23·8 t are for the electrical equipment.

The *Compagnie Electro-Mécanique, Paris,* got a very important order from the *Chemin de Fer de l'Etat (France)* for the electrical equipment of 23 D. C. locomotives, axle arrangement $2D_o2$ intended for the Paris-Le Mans line section (211 km) now to be electrified. They are very similar to locomotives $2D_o2$, Series E 503, delivered to the Paris-Orléans Railway in so far as the Brown Boveri individual axle drive and the electric equipment is concerned. The units delivered to the Paris-Orléans Railway give excellent results and can be considered as the most satisfactory express locomotives on any of the French railways which have electrified their systems to a more or less advanced degree.

We and our concessionaries got orders for the *electrical equipment* of a relatively large number of *thermo-electric locomotives* and motor coaches. Mention should be made of the electrical equipment of a *petrol-electric truck for electric-arc welding* built for the *Swiss Federal Railways* and consisting of a D. C. generator, a D. C. series-wound motor as driving unit and of a change-over controller. The petrol engine is by Zürcher, St. Aubin, to deliver 20 H. P. at 1500 r. p. m. for welding work and to deliver 27 H. P. at 2200 r. p. m. for driving the truck, for supplying cranes and lighting circuits on the site of repairs etc. The electric transmission is made possible by the generator, driven by the petrol engine, being both the welding generator and the power and control unit for the driving motor. The unit (Fig. 80) was delivered in July of last year and has given very satisfactory results as a self-propelling truck to carry out welding operations anywhere on the line, as a source of power supply to cranes and to light-

ing systems on the site of work being carried out, and as a line-inspection car, etc.

A much bigger order was that for the electrical equipment of four Diesel-electric motor coaches which was placed by the *Ferrocarril Provincial de Buenos Aires* with Messrs. Sulzer Bros., Winterthur, as general contractors. These motor coaches are each equipped

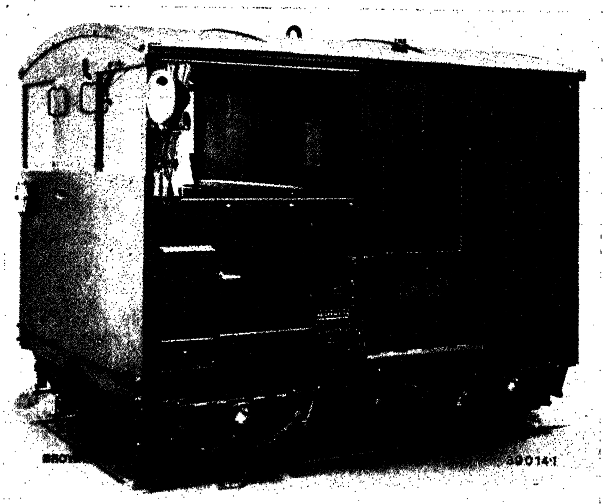


Fig. 80. — Petrol-electric truck for electric arc welding, built for the Swiss Federal Railways.

with a six-cylinder Diesel engine of 230 H. P. at 950 r. p. m. and have room for 62 passengers seated and for a luggage compartment of $3 \cdot 5$ m^2 floor surface. The weight of the coach ready for service and fully loaded is about 41 tons, the maximum speed 80 km/h, the tractive effort on the wheel tire (one-hour rating) is 1090 kg at $41 \cdot 5$ km/h. The main electrical equipment is composed of a main generator and an auxiliary generator for rigid coupling to the Diesel engine, two driving motors, the automatic main-generator excitation regulation by servo-field regulator, a lighting convertor set for transforming 145 V auxiliary voltage to 24 V lighting voltage and of the motor-driven compressor.

Four Diesel-electric motor coaches were also delivered for the *Madrid-Saragossa-Alicante Railway* (MZA), the electrical equipment of which was already described (see the Brown Boveri Review, 1934, page 185). This equipment was ordered and delivered in the course of last year.

Finally, two electric four-axle petrol-electric passenger coaches delivered by the former S. A. Westinghouse in Le Havre about 20 years ago and belonging to the *Chemins de Fer à voie étroite, Luxembourg,* were transformed and modernized. This transformation included the replacement of the petrol-electric set by a modern Diesel-electric set of 180/200 H. P. (the Diesel engine being by Humbold-Deutzmotoren A. G., Cologne) the replacement of both D. C. driving motors by motors of our own design of about 75 H. P., the enlargement of the existing cooling equipment, the putting in of a battery for starting up the Diesel engine from the generator side and for lighting purposes, the installation of a safety device of our design for one-man control and, finally, the mounting of modern control gear (see further on). After these changes have been carried out, the motor coaches should be able to travel with one or two trailers instead of singly as heretofore. The line section Diekirch-Vianden or vice versa should now be travelled over in 29 instead of 42 minutes. The maximum speed is to be about 60 km/h.

Tecnomasio Italiano Brown Boveri got an order from the *Stà. Italiana per le Strade Ferrate del Mediterraneo, Calabro-Lucane* for the electric equipment of ten Diesel-electric motor coaches each of 254 H. P. Each coach is to be equipped with two Saurer-Diesel engines direct-coupled to a generator and with two driving motors each of 74 kW at about 37 km/h rated speed, the maximum speed being 75 km/h. Each Diesel engine with its generator and a driving motor is mounted on one bogie. There is a motor-generator set on each coach for supplying the auxiliary services and the motor of this set can be supplied from either of the two generators. The coaches are equipped with our automatic servo-field-regulating control and also with the resistance braking and safety device equipment for one-man control.

The *Oesterreichische Brown Boveri Werke A.-G.,* in *Vienna* along with two other firms got an order from the *Austrian State Railways* for the equipment of two four-axle and one three-axle Diesel-electric motor coaches. The first two coaches each weighs 48 t and has two Diesel engines of 210 H. P., two generators and two driving motors which give a one-hour tractive effort of 2160 kg. The maximum speed is 110 km/h. Each generator works on its own driving motor. The three-axle coach weighs 30 t and has a 210-H. P. Diesel engine, one generator and two driving motors which develop a tractive effort of 1580 kg at the one-hour rating. The maximum speed is 85 km/h.

The *Czechoslovakian Brown Boveri Works* in *Prague* got an order from the *Czechoslovakiane State Railways* for the electrical equipment of two Diesel-electric motor coaches each with two Diesel

engines of 2 × 210 H.P. In each bogie is lodged a Diesel-generator set and one driving motor. The two driving motors develop together a one-hour's tractive effort of 1830 kg at 46·5 km/h, the maximum speed being 110 km/h. Control is by power relays as in the other motor coaches delivered to this railway. So as to retain the standard voltage of the lighting system of 24 V and be able to supply the lamps from the starting up battery, the latter is dimensioned for 48 V and the charging generators are connected in series.

In the field of *cable railways* and *rack railways,* we may mention here the order booked by *Tecnomasio Italiano Brown Boveri* in Milan for the electric equipment of two four-axle and one two-axle rack motor coaches for 600 V D. C. with four and two motors respectively each of 100 H.P. one-hour rating and intended for the *Turin-Superga* mountain railway.

We, ourselves, got the order for the electrical equipment of the *Unterwasser-Iltios* funicular railway. The winding gear of this railway is driven by an 80-kW three-phase motor. The plant is especially interesting on account of the remote-control from the coaches and the automatic regulation of speed at entering stations by means of a D.C. braking dynamo. This system is based on the experience gained with automatic regulating devices on the Davos-Parsenn funicular railway. The D. C. braking dynamo, a highly saturated D.C. series generator, is direct coupled to the driving motor of the winding gear and carries a small auxiliary winding for separate excitation. The D.C. machine is used to brake down the coaches to a given reduced speed, during which operation the power generated is consumed in a braking resistance. Braking is similar to that of a tramway coach when it is braked by short-circuiting. The braking effect adjusts itself automatically to the load.

The braking machine as well as the driving motor is controlled by a common controller driven by a servo motor. When the braking retardation at entering a station is too great, due to a heavy load in the ascending car, the braking effect of the D. C. machine is weaker because the braking resistance still in circuit and dependent on the switching speed of the controller is too great, as compared to the speed of the braking dynamo to permit of a stronger braking effect. When the load in the descending coach is heavy a greater braking effect is produced by the forced cutting out of resistances in the current circuit of the braking machine, this until the desired retardation is attained to allow the coaches to be slowed down to the reduced speed before reaching the final position where they are definitely stopped. This is necessary in order that the coaches should always stop at practically the same spot. According to service conditions it may be necessary to leave the driving motor switched in with the total rotor resistance during entry into the stations. This occurs, for example, when a heavy load is being brought up, in order to draw the coaches at reduced speed into the stations. When this occurs there is a condition of equilibrium between the loads of the motor and of the braking generator on the last braking step. The final braking down to a stop is effected by the ordinary service brake actuated electro-magnetically and is brought into action by the throwing over of a limit switch. This braking equipment allows of the simple and automatic adjustment of the starting and braking processes for heavy and fast running funicular trains without requiring a flywheel and without coupling devices with auxiliary motors as used on the Davos-Parsenn railway for entering stations. Remote control of the railway is carried out on a system similar to that of the Davos-Parsenn Railway and Fürigen funicular railways.

The railway was opened to the public on the 26th of July, 1934 and automatic control was used from the first. The car conductor touches the contact wire with a special rod thus setting the car in motion. The start and retardation before entering the station, as well as the stopping of the winding machinery, all take place in proper sequence smoothly and quite automatically. Fig. 81 shows one of the cars and Fig. 82 the machine room.

Certain lines in traction material were systematically developed by us in the course of last year and met with considerable success. This applies to our well known *D. C. axle-bearing motors* in the forced ventilated design of which another 100 were ordered partly from *Tecnomasio Italiano Brown Boveri* and partly from the Sarigliano firm to our design for *Turin Tramways (Azienda Tranviaria Municipale),* while the Triest Tramways ordered 4 × 20 motors of the same size for 20 four-axle tramway cars as well as 2 × 20 cam-type controllers with separate switching elements, 1 × 20 pantograph-type current collectors, 1 × 20 sets of resistances and 1 × 20 motor compressors.

Our new *current collector of statically determined design* met with great success. An interesting order booked by the *Cie. Electro-Mécanique,*

Paris, was that for 68 current collectors of the *Métropolitain de Paris* (Paris-Luxembourg-Sceaux-Robinson line). These are current collectors of light design with vertically-sprung contact piece supports, for 1500 V D. C., 100 A and up to a speed of 100 km/h with contact wire having catanary suspension. The current collectors are built, according to American practice for being raised by spring pressure and for lowering by compressed air pressure and with a catch device in the low position which can be released by compressed air. The effective straight length of the contact piece is 960 mm, the total length 1670 mm. The current collector is very low being only 324 mm high when lowered, this including protective distancing; all current-carrying parts being separated from the coach roof by at least 90 mm,

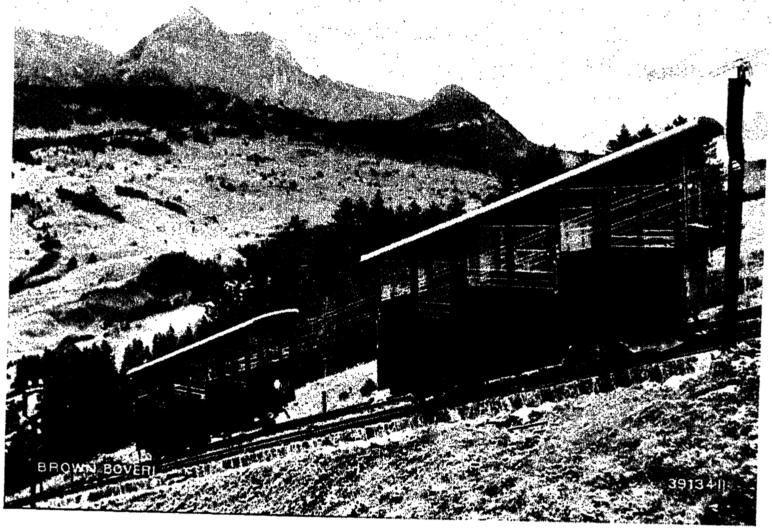


Fig. 81. — Unterwasser-Iltios Funicular Railway (Switzerland). The two coaches on the turn-out.

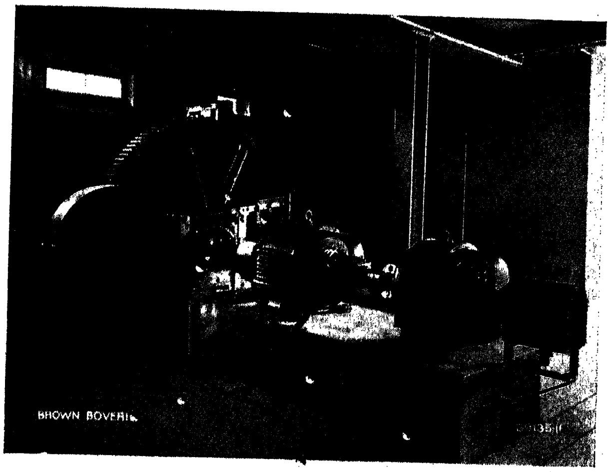


Fig. 82. — Unterwasser-Iltios Funicular Railway (Switzerland). View of the machine room.

so that only 234 mm remain for the constructive height proper of the current collector.

We are delivering 170 current collectors to the *Basle Tramways* also of our static design, first with aluminium contact pieces to be replaced later on by carbon pieces, which cause much less sparking if the contact wire is polished and, thus, much less wireless trouble on receiving sets than aluminium contact pieces.

The *cardan drive* of *train-lighting dynamos*, which was mentioned in an earlier number of the Review has been considerably developed. It was found that it was not always possible to mount the train-lighting machine parallel to the longitudinal axis of the bogie, that is to say this arrangement was too dependent on the design of the bogie frame, the arrangement of the carrying springs and of the spring bolster of the bogie. We have, therefore, developed a new design in which the lighting machine is suspended on the front side of the bogie frame with its axis parallel to the running axles and is driven by two concical gear wheels and two cardan couplings.

The arrangement with two separate reduction gears gives great latitude in the choice of the total speed reduction ratio. A drive of this type was built into a Swiss Federal Railway coach Type AB 4 ü (Fig. 83). The lighting generator delivers about 4 kW at 36—45 V. The overall gear ratio is 1 : 2·768, the diameter of the coach wheel being 730 mm. The coach is now in service after a number of trial runs up to speeds of 110 km/h.

Finally, we can report that railway authorities are showing lively interest in the *air-heating system for railway coaches* developed by us; this system

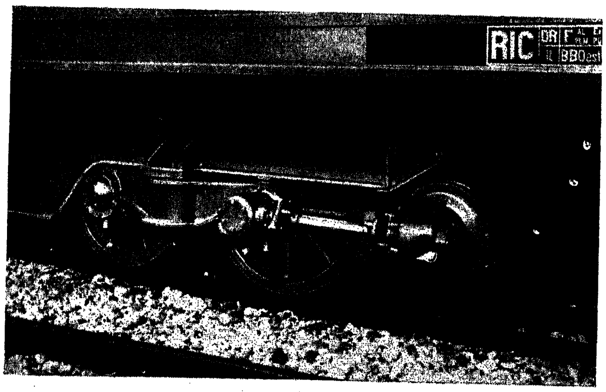


Fig. 83. — Drive of a train-lighting generator by means of a double Cardan shaft, built into a new type of bogie by the Swiss Locomotive and Machine Works, Winterthur.

should have a great future before it, on account of its simplicity and because it can be used with different heating voltages. Another advantage of this system is that the hot air does not collect under the seats, as happens with separate heating units, but is carried to the parts of the coach where it is really wanted. This advantage is apparent in the short-heating-up period required with our system. A further advantage is that the fan used to renew the air in the compartments can also be used in summer. We had the opportunity of introducing our air-heating system on eight coaches of the *Swiss Federal Railways,* apart from the first two coaches thus equipped and built for changing over from 3000 V to 1500 V D. C. and 1000 V A. C. (16 ²/₃ and 50 cycles). The new coaches are the two light motor coaches in course of construction, Type CLe 2/4 for 220 V A. C. and six ABC 4 ü coaches of which four are for 1000 V A. C. and two for changing over from 3000 V to 1500 V D. C. or 1000 V A. C. (16 ²/₃ and 50 cycles). To these must be added two modern four-axle postal coaches for 1000 V A. C. of the *Federal Post and Telegraph Administration in Berne.*

II. THE WORK OF THE TURBINE DEPARTMENT.

Our steam-turbine shops, which work, practically, for export business alone and in rare cases only for the inland market, have been especially hard hit by the industrial crisis and the shackles placed on free commercial exchange. Although activity could only be maintained at the cost of great sacrifices, development and research work were resolutely pursued in the course of the past year. At the same time every effort was made to render our turbines competitive on the world market, by practical improvements, the simplification of existing designs and the adaptation of same to the requirements of the moment.

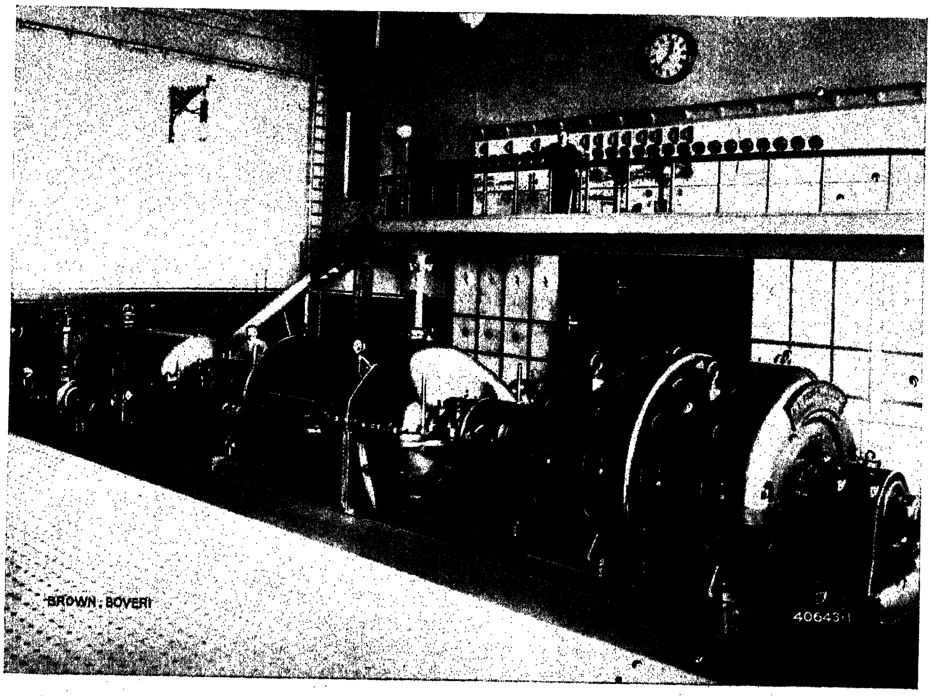


Fig. 84. — The first steam turbine built on the Continent, in the year 1902, 5000 H.P., for Francfort a/M. Although the heat drop was small, it was found necessary to use a two-cylinder design with numerous stages, because the constructive methods and the materials used at that period only allowed of low peripheral blade speeds.

(1) *Steam turbines.*

In steam-turbine design, the question of "multi-cylinder or single-cylinder turbine" has been brought to the fore again, although it was considered to have been definitely settled in favour of the multi-cylinder machine, as adopted in all recent big plants. Taking into consideration the historic development of the steam turbine and in view of our own extensive experience in the field, we venture to express an opinion on this question.

As is known, a steam turbine, in order to be efficient, must have, for a given heat drop, a sufficient number of rows of blades rotating at definite peripheral speeds; also the lower the peripheral speed imposed by constructive reasons, for example, the greater must be the number of blade rows. Further, a turbine with a small initial volume of steam, i. e. of low power or one working with a high steam pressure, requires, for a given r. p. m., many small-diameter stages, because, in order that the blades

should not be too short, they must be mounted on discs or drums of small diameter. When the volumes of steam dealt with are considerable, the blades are of an advantageous length, even on big discs, so that the turbine can be built with a smaller number of blade rows of big diameter.

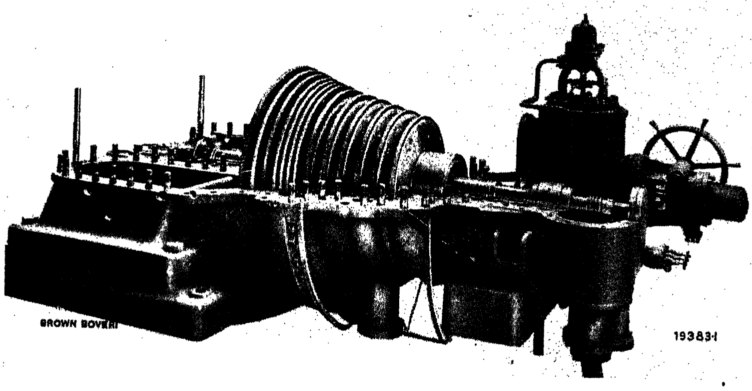


Fig. 85. — Big single-cylinder steam turbine of about the year 1924.
By increasing the peripheral speed it was found possible to utilize bigger heat drops in a single-cylinder turbine.

Although, in the initial stages of steam-turbine development, only low steam pressures were used and moderate efficiencies were considered satisfactory, a great number of blade rows were necessary as the materials used at that period only permitted of low peripheral speeds. For instance, the first steam turbine ordered from Brown Boveri in the year 1901, which was a 5000 H.P. unit for Francfort a/M, was built for only 1360 r. p. m. and had 83 rows of blades, which had to be lodged in *two* housings. Thus, the first steam turbine built on the Continent was of the two-cylinder type (Fig. 84).

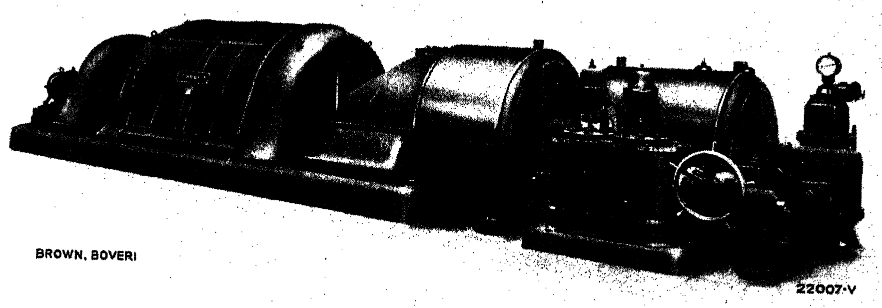


Fig. 86. — Two-cylinder machine of about the year 1927.
The further increase in the heat drop and demand for better efficiencies made two-cylinders necessary, in order to be able to lodge a big number of rows of blades.

However, means were soon found to increase the peripheral speeds and, thus, to reduce the number of rows of blades, while making more advantageous and greater use of the heat drop, so that all the discs could be lodged in *one* housing. This principle of single-cylinder design held its own for 20 years, especially during the war period (Fig. 85). This period was succeeded by the post-war years of very high coal prices accompanied by great efforts to improve the efficacity of thermal machinery, etc. Steam pressures which, on an average, had been about 12 kg/cm² were increased, in the course of a few years, so that the average pressure was between 20 and 30 kg/cm² — in a few exceptional cases up to 130 kg/cm². In order to utilize these increased pressures and heat drops, more rows of blades had to be crowded into the turbine and, further, each row of blades designed to utilize an ever-increasing heat drop. Soon, however, it became impossible to utilize the higher pressures with the desired efficiency because the single-cylinder machines were too small and thus the two-cylinder turbine came into its own again (Fig. 86). It had been recognized that, with the high price of coal prevailing, it was more economical to purchase a somewhat more expensive turbine and to save on fuel, an argument which was strengthened by the fact that the lower steam consumption meant smaller boiler and condensing plants.

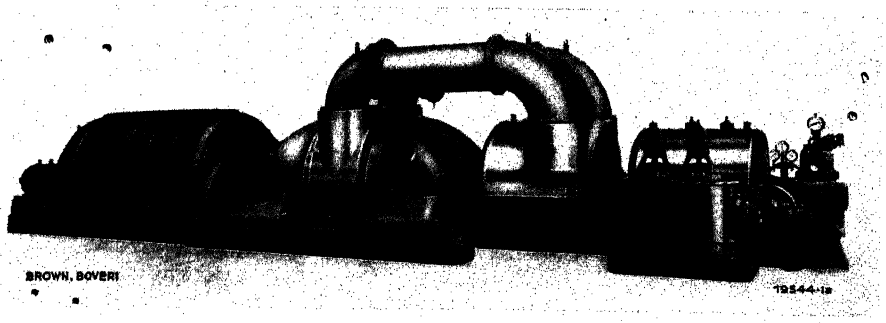


Fig. 87. — Big three-cylinder steam turbine of about the year 1927 for outputs of 20—40,000 kW.
The big outputs and higher vacuums used made it necessary to duplicate the outlet ducts and led to the three-cylinder turbine.

Simultaneously, considerable improvements were carried out as regards the degree of vacuum of the condensing plant, and this meant that the volumes of exhaust steam to be handled at the exhaust end of the turbine were so much increased that, for big outputs, the lowest-pressure blading had to be arranged in two parallel halves. This led to the *three-cylinder turbine* as shown in Fig. 87. This three-cylinder machine is suitable for all pressures from 20 up to 130 kg/cm^2 and especially, for high temperatures, as well, because the high-pressure housing at high temperature is separated from the parts at lower temperatures.

To-day, a decade later, in a severe industrial crisis, the situation seems to have changed, once again. The price of coal is about one quarter of its post-war peak price while, in many countries, the capital available for new plants, is small. There is a demand for cheaper machines even though their coal consumption be not as low as it might be and there is a tendency noticeable, here and there, to go back to the single-cylinder turbine even for high steam pressures despite somewhat lower efficiencies. There is no denying that, for outputs of the order of 20,000 to 30,000 kW, the single-cylinder turbine is the most economic machine for plants with pressures up to about 20 kg/cm^2 and that it will be used in cases where, for any reason, the pressure cannot be increased. The cheaper single-cylinder machine is also justified for higher pressures in cases where the unit is to be used as a spare, the fuel consumption of which is a factor of no importance as the machine runs for short periods only. In steam-turbine stations under continuous load, it will, however, be found possible, in most cases, to use an old unit as spare and to purchase a new turbine, working to highest efficiency, for continuous service, a policy which will generally be found to be justified by the calculations of plant economy. Finally, a single-cylinder machine will be found necessary when a dimension of the existing buildings do not admit of a multi-cylinder unit being put in.

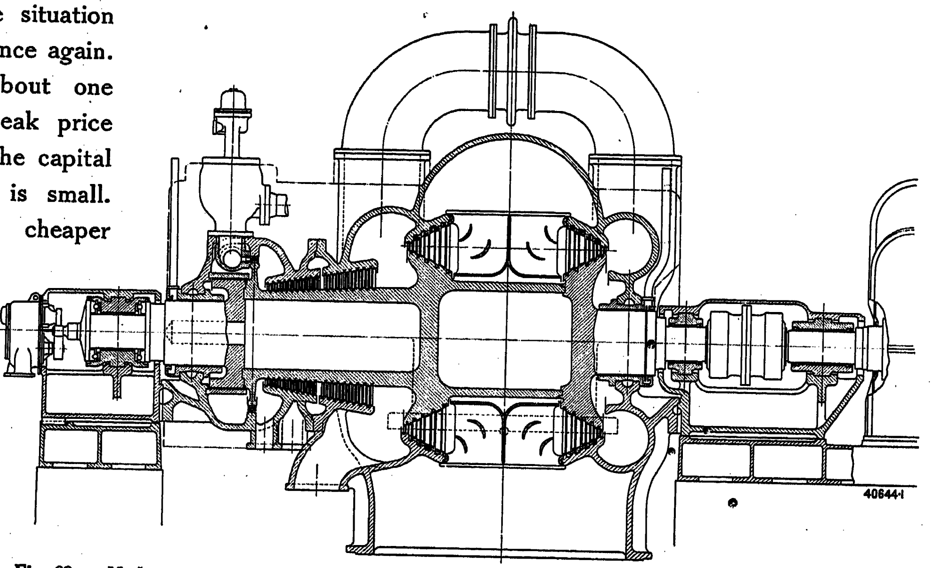


Fig. 88. — **Modern single-cylinder turbine with double steam exhaust ducts, for outputs up to 35,000 kW.** For pressures up to 20 kg/cm^2 abs, this type of turbine gives high efficiencies; it can also be used for pressures up to about 45 kg/cm^2 in plants where high efficiency is not a decisive factor.

In order to take these desires into account, Brown Boveri developed a big *single-cylinder turbine* in the course of the preceding year, shown in section in Fig. 88. This unit is designed for an output of 25,000 to 35,000 kW, a steam pressure of 20 to 25 kg/cm^2 and temperatures up to 450^0 C; it can, however, be used for a steam pressure of 45 kg/cm^2. The relatively big volume of steam allows of big blade diameters in the high-pressure part and thus of attaining a relatively high efficiency with a small number of rows of blades only. On the other hand, the big volume of exhaust steam to be handled made it necessary to divide the steam flow of the low-pressure part into two parallel flows opening into a common exhaust duct. The shaft is built up of discs and drums welded together, a design which is patented and has given the best results in practice; it eliminates wheel discs coming loose, keys being thrown off, etc. and thus prevents vibrations. After having passed through the regulating valve, the steam is led to special nozzle chests of material impervious to high temperatures, secured in the turbine housing according to a patented method. Thus, these turbines are suitable for the highest steam temperatures as the housing proper only contains steam which has been already utilized in the first two-stage impulse wheel and is at a relatively moderate temperature.

When we come to steam pressures of 25—45 kg/cm^2, the efficiency of three-cylinder turbines is about 3—5 % higher than that of the single-cylinder unit and the same applies to its output for a given

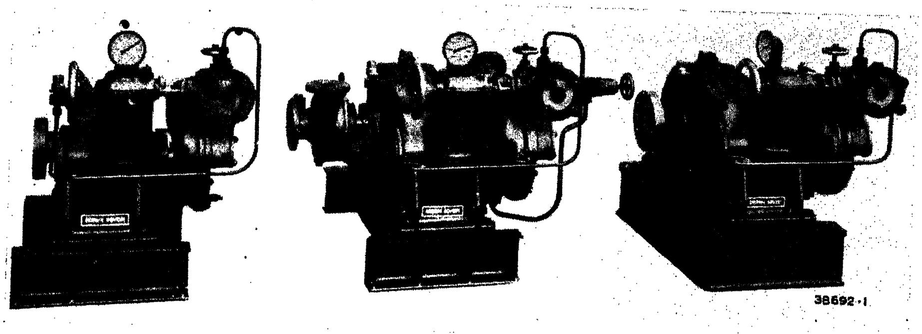


Fig. 89. — Small back-pressure turbine with mechanical governor gear to drive electric generators and auxiliaries of all kinds.

been running for about three years, having operated for about 19,000 service hours and delivered 165,000,000 kWh.

To summarize, we would say that, in our opinion, the single-cylinder turbine is advisable for pressures below 20 — 25 kg/cm² and the multi-cylinder turbine for pressures between 20 and 45 kg/cm², for machines under continuous load. For pressure above 45 kg/cm² the three-cylinder turbine is necessary.

amount of steam available. In power plants where the machine runs regularly, the multi-cylinder turbine pays for its higher purchasing price, in a few years, even to-day with the very low cost of fuel (which may not last). Further, for reasons of efficiency, it would not be logical to build boilers and pipe lines for high pressures and then not make the best possible use thereof in the turbines.

With pressures above 45 kg/cm², a multi-cylinder unit *must* be used, and it should be mentioned here that the standard Brown Boveri three-cylinder turbine is very suitable indeed for highest pressures which can be used to economic advantage, i. e. up to about 130 kg/cm². This three-cylinder high-pressure turbine is perfectly reliable in service, as is fully proved from the running sheet for the Brown Boveri, high-pressure turbine, 36,000 kW, 130 at. gauge, delivered to the Witkowitz Coal Mine which has

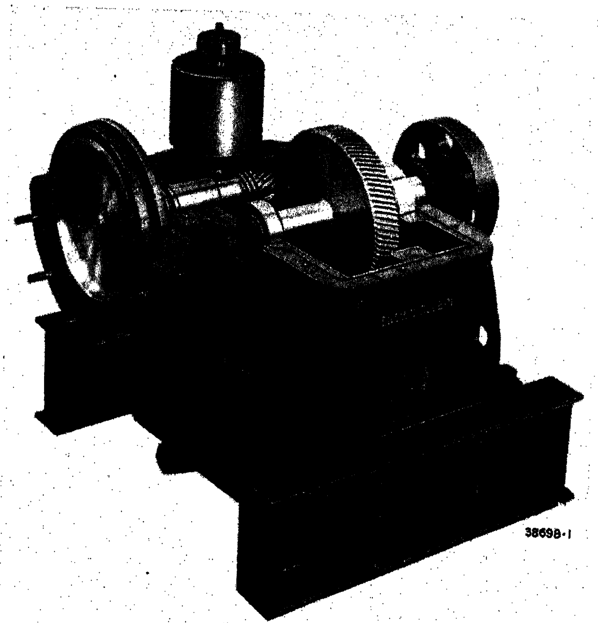


Fig. 90. — Small back-pressure turbine with mechanical governor gear, open.

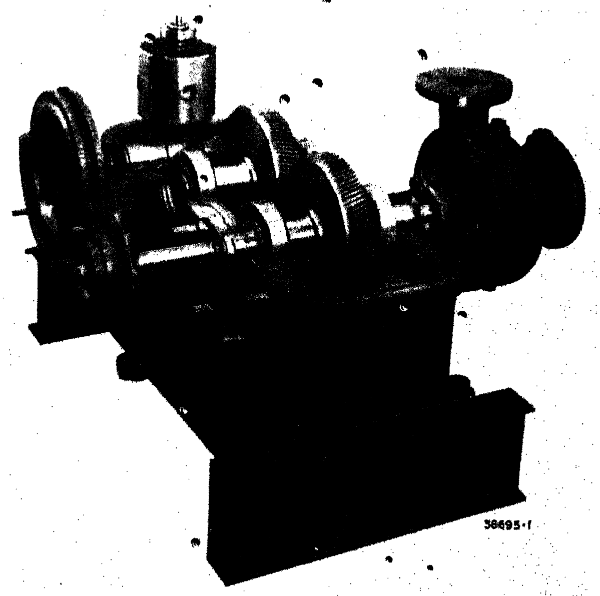


Fig. 91. — Small back-pressure turbine, open, with built-on pumps.

The old idea of generating the steam necessary for heating or for industrial processes at higher pressures and first expanding it in a back-pressure turbine or in an extraction turbine to generate electric power, is being applied more and more frequently, to-day and this in small plants, as well. This has meant a remarkable increase in the number of small *back-pressure turbines* delivered. We have created, lately, new types intended for standard use or as auxiliary units. They can be utilized for pressures up to 40 kg/cm², temperature up to 450° C, back-pressures up to 5 kg/cm² abs and for outputs up to 450 kW. These small turbines are regulated by a centrifugal governor. In the smallest turbine types, this governor operates the single regulating valve directly, having

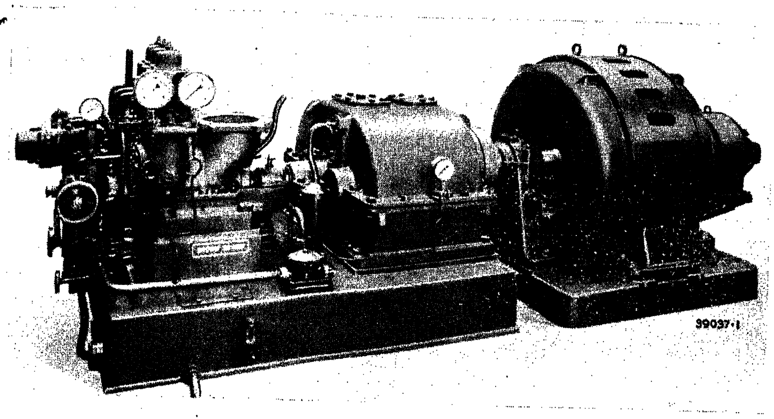


Fig. 92. — Small back-pressure turbine for outputs up to 450 kW with 3 nozzle-regulating valves and Brown Boveri oil-pressure governing system.

a hand-operated overload valve connected beside it. As in bigger turbines, of 50 kW and upwards, good efficiencies are generally called for at half, full and overload, these machines are equipped with nozzle-valve regulation, actuated by a system similar to the standard Brown Boveri oil-pressure governing. The new Brown Boveri small turbine is a very reliable unit, in service, operating at an excellent efficiency. Fig. 89 shows three small turbines for outputs up to 50 kW, with mechanical governing gear; the two outer ones are for driving a generator and the one in the centre for driving built-on pumps. Fig. 90 shows the turbine open, the turbine wheel, the reduction gear and the centrifugal regulator being visible. Fig. 91 shows the same turbine, open, with pumps built on. Fig. 92 shows a back-pressure type of turbine for outputs up to 450 kW with nozzle valves and Brown Boveri oil-pressure governing system.

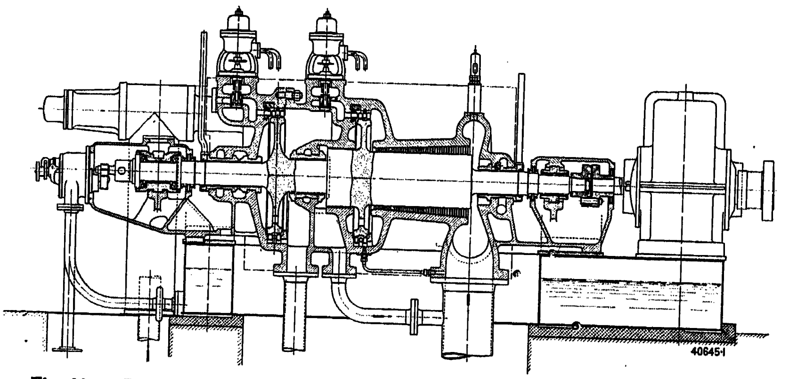


Fig. 93. — Extraction back-pressure turbine for 900 kW, 35 kg/cm² live-steam pressure, 12 kg/cm² abs extraction pressure and 1 kg/cm² abs back-pressure.
The high and low-pressure parts have their own governing gear with nozzle-regulating valves.

In industrial heating power stations, two pressures for heating steam are often used, one, for example, for industrial heating proper and one for heating rooms. In this case *extraction-back pressure turbines* or *double extraction turbines* with condensation are used. Fig. 93 shows an extraction back-pressure turbine for an output of 900 kW at a live-steam pressure of 35 kg/cm² abs, 12 kg/cm² abs extraction pressure and 1 kg/cm² abs back pressure. The turbine is essentially composed of a single-disc back-pressure turbine with its governing gear, supplied with steam at 35 kg/cm² abs and which delivers steam to the steam system at 12 kg/cm² abs and of a combined back-pressure turbine which also has its own governing gear, supplied with steam from the system at 12 kg/cm² abs and, itself, supplying a system at 1 kg/cm². Both turbines, however, are in one housing and on a common shaft which drives a single-generator, thus forming an extraction back-pressure turbine.

An especially interesting turbine is that shown in Fig. 94. It is a combination of a first-stage turbine with an extraction back-pressure turbine, placed in a power station having a new high-pressure steam plant with steam boilers for a pressure of 95 kg/cm² abs and an old steam plant with boilers and turbines at 20 kg/cm² abs. The first-stage turbine is employed to utilize the high-pressure steam of the new boiler plant while the extraction back-pressure turbine is used to preheat the feed water of the new and of the old boiler plant. In the high-pressure first-stage turbine, seen on the right, about 140 t of steam per hour are expanded from 95 down to 20 kg/cm² abs and led to the old low-pressure steam system in the station. In the preheating turbine, seen on the left, about 20 t of steam per hour at 20 kg/cm² abs are partly expanded down to 10 and partly to 4 kg/cm² abs The preheating of the feed water for the old plant is carried out at 4 and 10 kg/cm² abs and that of the high-pressure boiler at 4, 10 and 20 kg/cm² abs.

In a modern high-pressure power station in which the steam is expanded down in a turbine from the high pressure to that in the condenser the feed water is, usually — which is also our standard practice — preheated in different stages by means of steam extracted at various pressures from the main turbine. This gives, automatically, suitable adaptation of the

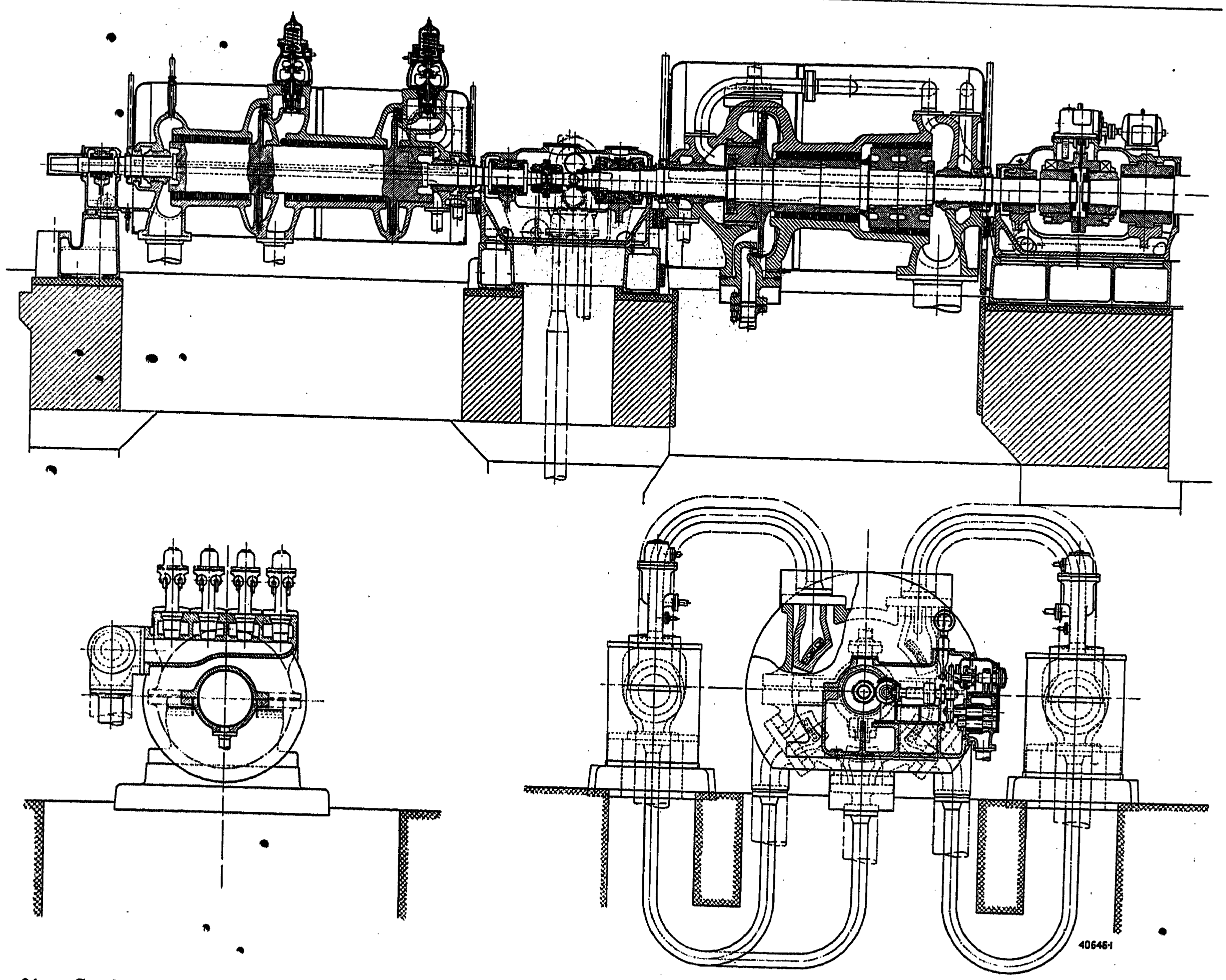


Fig. 94. — Combination of a first-stage turbine and of a preheating turbine, in a power station having an old steam-distributing system at 20 kg/cm² abs and a new one at 95 kg/cm² abs.

The steam from the high-pressure boilers is utilized in the high-pressure first-stage turbine, seen on the right, and it is then discharged to the low-pressure system. With the help of the preheating turbine, on the left, it was possible to realize the gradual preheating of the feed water, in the old power station.

preheating to the different loads. Contrary to this practice, some firms recommend that the feed water should be preheated by a special preheating turbine, the whole steam output of which is used to heat the condensate and the power output to drive auxiliaries. The power generated, however, at small partial loads of the main turbine, that is when the volume of feed water and of heating steam is low, is not sufficient to drive the auxiliaries so that extra power must be drawn from a motor or a condensing turbine which complicates the plant. Preheating with a separate preheating turbine is right and, indeed, necessary when the turbine cannot be tapped, as in an old power station which has got to be equipped for feed-water preheating. In new stations, however, in which the steam is expanded down from high pressure to condensation, our experience shows that the proper solution is to preheat the feed water by direct extraction of steam from the main turbine as this is cheaper, gives better efficiency, is more reliable and simpler.

(2) *Velox.*

The *Velox steam generator* has been further developed and perfected. A considerable simplification was introduced by lodging the superheater elements inside the evaporating elements. Fig. 95 shows an evaporating element with the coil of the superheater which is partly withdrawn in the illustration. The lower part of the element is purely an evaporating part while the upper part serves partly for evaporation and partly for superheating. In the whole element the Velox principle prevails, namely a high gas velocity with high coefficients of heat transmission so that it is possible to attain the desired results with very small heating and superheating surfaces.

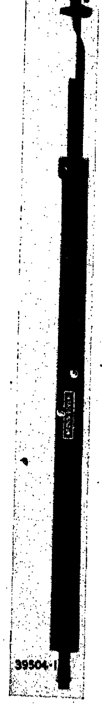


Fig. 95. — Evaporator element of a Velox steam generator with built-in superheater, slightly withdrawn in the illustration.

ACCEPTANCE TESTS ON VELOX STEAM GENERATORS.

Plant:	**Toulon Power station of the Soc. de Gas et de l'Electr. du Sud-Est**				**Haifa Power Station of the Palestine Electric Co.**	**Mondeville Power Station of the Soc. Métallurgique de Normandie**			
Authorities supervising test:	Tests were made on 31st July and 1st August 34 by the Association des propriétaires d'appareils à vapeur et électriques du Sud-Est				Tests were made on 2nd August 34 on our test bed by Prof. Dr. A. Stodola, Zurich	Tests were made on 24th and 25th January 34 by the Société Assoc. Normande des Propr. d'Appar. à Vapeur.			
Test	1	2	3	4	1	1	2	3	4
Load	minimal	1/4	2/4	4/4	Full load	Full load			
Full	Fuel oil with Hu = 9669 kcal/kg				Fuel oil with Hu = 9517 kcal/kg	Blast-furnace gas			
Fuel consumption . . . kg/h	244	498	1001	1902·8	2842	11798	11871	11350	11813
						(dry blast furnace gas)			
Gas temp. at outlet of feed water preheater . °C	82	77·4	96	113	128·7	112·6	108·2	114·1	116·3
Water and steam:									
Steam generated . . . kg/h	2982	6575	13150	24480	33700	11287	11687	10934	11098
Live steam at superheater outlet in . . kg/cm² abs	19·14	19·09	18·65	17·30	28·2	14·28	14·54	14·31	14·61
Temperature of steam at the superheater outlet in . °C	295·8	313·0	346·4	372·3	461·8	422·95	416·91	425·45	433·39
Feed-water temperature in °C	45·3	39·5	42·2	48·3	55·4	35·75	36·33	40·36	41·02
Power taken by auxiliaries:									
Power measured at terminals of additional motor to blower set in . . . . . . kW	7·7	13·9	11·1	32·8	— 5,2	118·5	123	133·5	116·75
Total for auxiliaries not including feed-water pump kW	46·8	54·3	49·2	78·7	50·5	155·23	159·87	171·07	154·14
*Overall plant efficiency *) . %*	*77·0*	*89·3*	*93·4*	*93·0*	*92·6*	*89 **)*	*89·5*	*86·6*	*86*
Notes taken from the reports on the acceptance tests:	The results show that all the guaranteed efficiencies were attained and even considerably surpassed. The great adaptability of the steam generator and the quality of the automatic regulation were particularly noticed. There was absolutely no smoke produced during the test.				The completely automatic regulating gear gave smooth transition to new conditions even after violent load fluctuations. When preheated the generator could begin steam delivery at once and reach full load in 4 min. The Velox has an extensive field of development before it in the sphere of reserve power plants and peak power plants for which there are many other alternative solutions, this even when the cost of fuel oil is such as to preclude its use for continuous service.	Very satisfactory results. No faults were revealed during the test either in the Velox machinery proper or in the regulating epuipment.			

*) $\eta_A = \frac{\text{Heat in steam — fuel preheating — 4000} \times \text{kilowatts absorbed by all auxiliaries}}{\text{Quantity of fuel} \times \text{Hu (net calorific value)}}$

**) On account of a poorer heat mixture and higher suction temperatures, great compressor power than with oil Velox plants is required.

All these tests show very high efficiencies. The fact that the high efficiency is also attained at low loads, the immediate adaptability to service requirements and the saving in attendance, result, in many cases, in Velox running charges being hardly above those of coal fired boilers, despite higher cost of oil fuel.

Fig. 96 gives a section through the new Velox steam generator. The oil flame is above. The gases stream out of the combustion chamber from below, passing through the evaporating tubes and past the superheater tubes, to reach the upper collecting chamber; from here they travel to the gas turbine and then to the preheater lodged in the flue. Thus, a separate superheater housing, as used before, is eliminated. As the gases reach the gas-collecting chamber at a temperature of only about 450—500° C, the latter does not require to be cooled. The new design is thus simpler than the old one in which the gas collector chamber and the housing of the superheater had to be cooled or covered in with fireproof masonry.

In the meantime, further acceptance tests have been carried out on Velox steam generators, the main results of which have been set out in the accompanying table.

The Toulon plant (Fig. 97) is used as a peak-load and spare unit for the town of Toulon which is supplied with power under ordinary conditions by hydro-electric stations over relatively long transmission lines. The Velox plant was called on to run under the most favour-

able conditions attainable "en veilleuse" that is to say in a state of instantaneous readiness to take over power delivery if a supply line happened to fail. With this object, the Velox works with a 4000-kW Brown Boveri turbine which runs empty on the system, the generator being able, if required, to work as a phase advancer to deliver wattless current on the point of consumption. The tests made with this kind of service have shown the Velox, despite the no-load service, to have an industrial efficiency of 77 % and a thermal one of 83·7 % taking the consumption of all auxiliaries into account. Under these conditions, the Velox, which can generate up to 28 t of steam per hour, produced about 3 t of steam per hour. A circuit breaker connecting one of the transmission lines from the hydraulic power house, was tripped, as a result of which the turbo-set and the Velox took over the load, fully automatically. A plant of this type thus acts as a momentary spare just like a steam accumulator. *A Velox power plant replaces a steam accumulator entirely* while having the essential advantage of not being limited to the delivery of a restricted amount of stored power available during a few minutes only but of being able to operate as a power-generating plant at any moment and for as long as is necessary. In No. 1 of the Brown Boveri Review of 1929 we proved that the cost of production of peak power and the capital outlay required for the power plant when using the steam boilers and turbines which were modern at that time and which could be heavily overloaded, was less than if heat accumulators were used. These considerations are still more justified in the case of the Velox peak power plant. The capital outlay required, the economic factor, the power available and readiness for service are all better in the case of the Velox plant. Further, if a Velox is used, it is often possible to install a sufficiently powerful peak-load plant in an existing station, without altering the buildings.

Again referring to Toulon, mention should be made of a test on starting-up time. It was found possible to start up the Velox, from the cold state and bring it to a full head of steam, in 6 minutes 11 seconds, further, to put it under full load in 1 minute 20 seconds more, making $7^{1}/_{2}$ minutes in all.

These acceptance tests give very high efficiencies. They prove that the Velox constitutes a big forward stride in the application of the steam cycle and we feel convinced that this development in conjunction with the application of high steam pressures and temperature and the

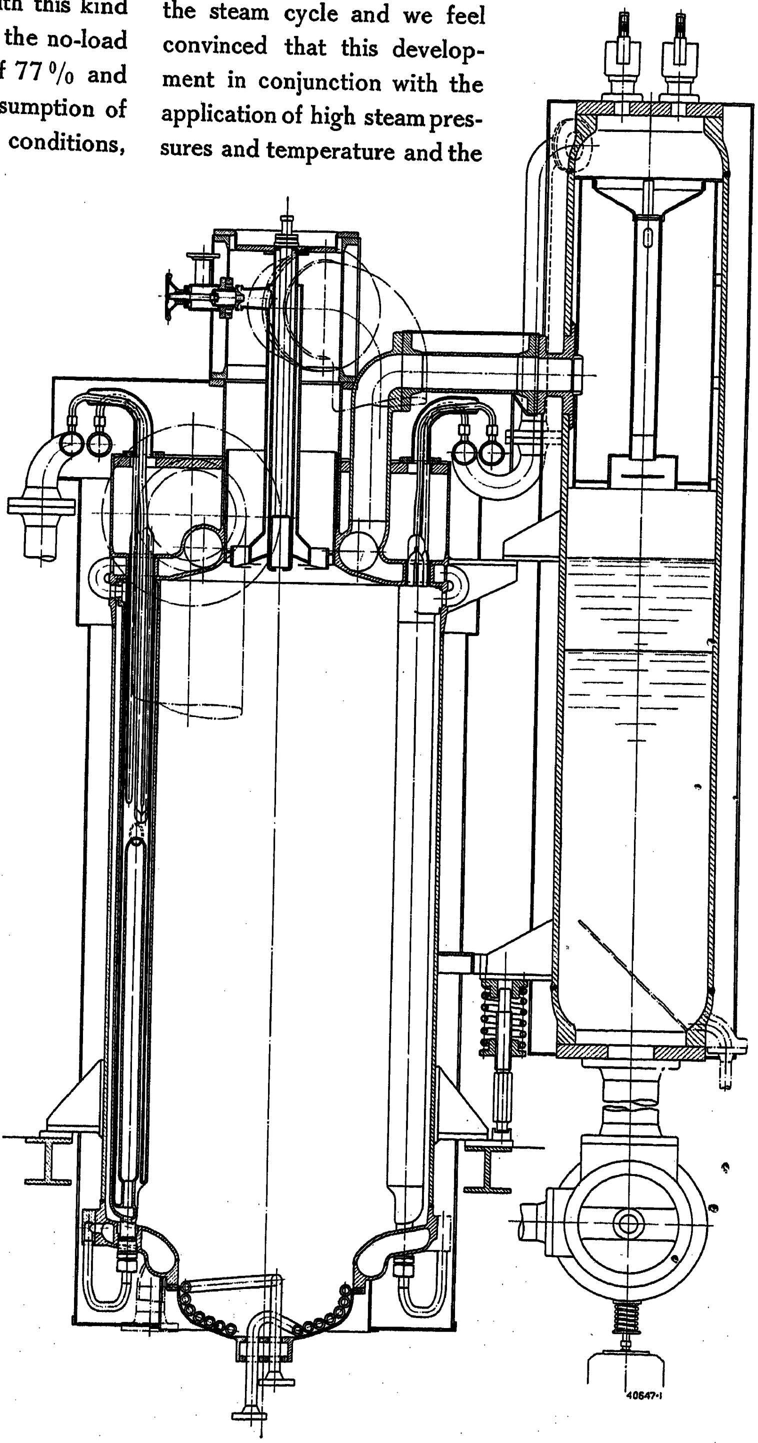


Fig. 96. — Section through a Velox steam generator with built-in superheater.
No special superheater housing is necessary.

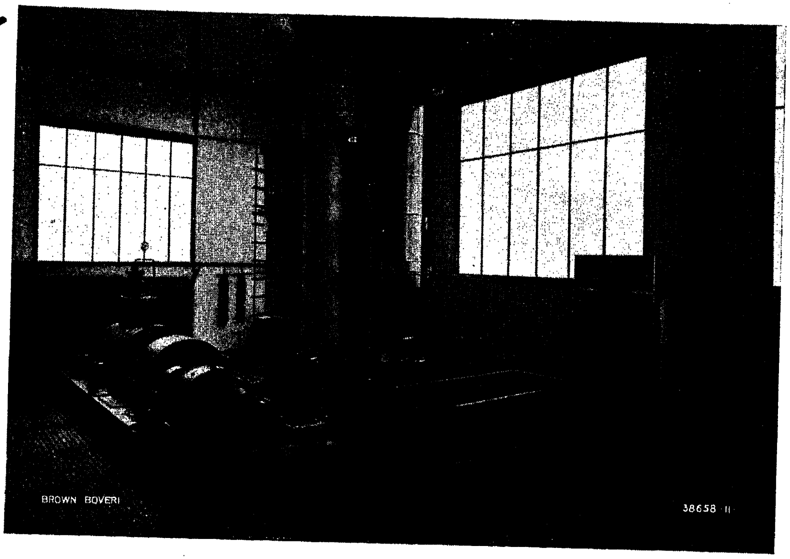


Fig. 97. — Velox steam generator of the Soc. de Gas et d'Electricité du Sud-Est. Centrale de la Loubière, Toulon.

The Velox operates every evening as a peak steam generator and is used with a 4000-kW Brown Boveri turbine as a spare in summer, during storms, to relieve the remote hydraulic station. The Velox and the turbine then operate "en veilleuse", running under no load and ready to take over load automatically when trouble occurs.

fact that any cheap oil can be used for fuel will allow the Velox with turbine to compete successfully with big Diesel units.

The *Velox heat generator* is especially suitable to purely heating plants or to heating power plants because of its smokeless combustion. These plants are usually in inhabited quarters or expensive blocks of buildings such as hospitals, technical colleges, university buildings, business houses, etc. Coal as a heating fuel is undesirable on account of the soot and smoke engendered even under the best of circumstances. We might refer here to the efforts expended to eliminate soot after the installation of the central heating plant in the Swiss Federal Institute of Technology, Zurich. The coal supply to heating plants generally takes place under conditions which are unsuitable in business or administration buildings (although it happens that the coal supply to the Zurich plant takes place under perfect conditions, thanks to a tunnel of the Swiss Federal Railway system passing below the building of the Institute). Oil fuel, on the contrary, can be brought in in tank cars without causing trouble. The same motives which led to the adoption of oil fuel for passenger vessels and warships will, certainly, lead to the use of oil for central heating plants in towns.

The Velox heat generator is also the best type of heating boiler for burning the relatively expensive oil with a high efficiency. A heating boiler rarely operates at its full load; it is generally working to small fractional loads. Now the Velox heat generator has a quality which is much appreciated in heating plants, namely that the amount of heat generated can be adjusted to the demand instantaneously and it can be stopped or started up again without losses, while the very high efficiency at full load is maintained practically unchanged down to quite small loads. This high efficiency at full and partial loads coupled to the adaptability of the amount of heat generated to the requirements are the reasons why the Velox-heat generator hardly costs more in fuel than a coal burning boiler despite the higher price

Fig. 16. — Two Velox heat generators in the Aarau Cantonal Hospital.

The two heat generators are used for peaks and as spares in a heating system which is advantageously supplied by waste power from the hydro-electric municipal works.

of oil. If the Velox is only wanted to cover peaks and has to work along with coal-heated boilers or electric heaters, the cost of fuel ceases to be a factor of importance, in any case.

Most heating plants must be placed in quarters where the cost of land rules high. The Velox heat generator, as is known, only takes up about $^1/_5$ of the space required by a coal-fuel plant and, being very light, can be placed in a lower or upper storey, as found needful. The savings effected in space and buildings cover a great part of the cost of the heat generator.

All these qualities have already allowed Brown Boveri and their licensees to place six Velox heat generators with clients in course of the last year. Fig. 98 shows two Velox plants in the Aarau Cantonal Hospital which are spares and peak-load heat generators for winter and supply a network of heating pipes. The ground load is carried by the hydro-electric municipal works which uses waste power for this purpose. A similar plant is going into the Ciudad Universitaria Madrid and two further ones into the Città Universitaria, Roma.

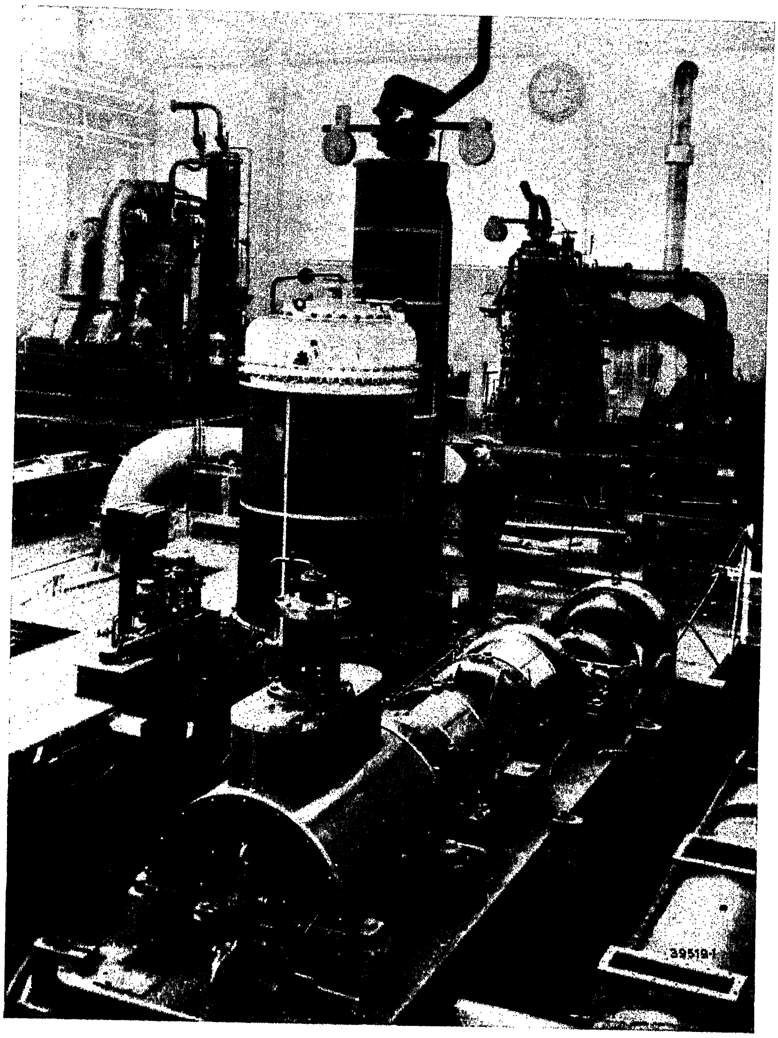


Fig. 100. — Three Velox steam generators, for 16–18 t/h on the Baden test bed.
The Velox are erected in the shops with all their auxiliaries and are tested under full load. This shortens and simplifies erection and setting to work on site.

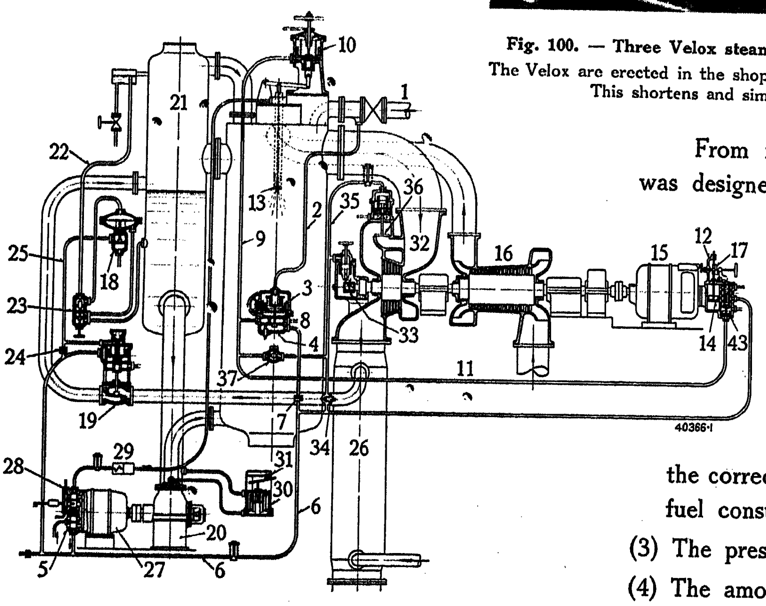


Fig. 99. — Governing diagram of a Velox steam generator.
The Velox works quite automatically. The fuel supply is regulated according to the load and the combustion-air quantity is regulated according to the amount of fuel. Steam pressure and water level are kept constant automatically and if the water feed fails, the fuel supply is cut off.

From its inception, the Velox steam generator was designed with a *completely automatic governing equipment* which eliminates the need of continuous attendance. This equipment fulfills the following duties:—

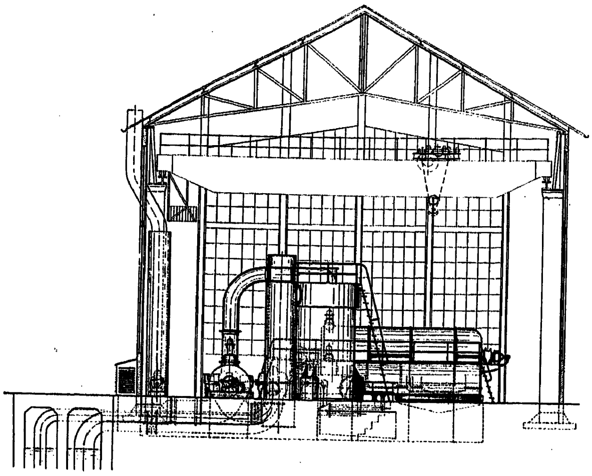
(1) The amount of fuel supplied is regulated to meet consumption.

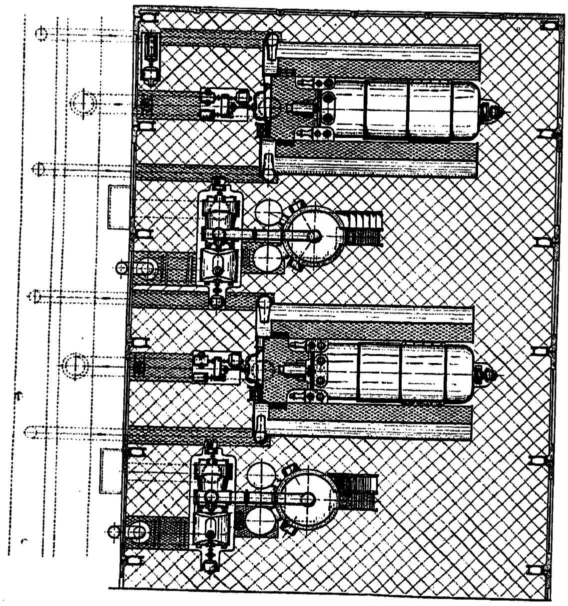
(2) The amount of air requisite for the combustion is maintained in exactly the correct proportion to the fuel to give the best fuel consumption.

(3) The pressure of the steam is maintained constant.

(4) The amount of water in the evaporator is maintained constant by means of automating feeding.

(5) If the circulating pump or the feed water supply fails, as may happen if the current fails, the supply of fuel and, consequently the Velox, are cut out.





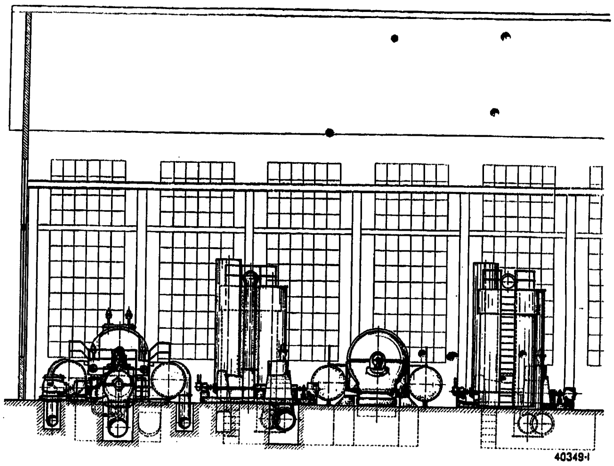


Fig. 101. — Velox power plant.

The Velox and the turbine form a single unit. There are no long pipe branches and accessoires thereto. The Velox auxiliaries and those of the condensing plant are driven together from the main turbine and the charging set is driven by gas and steam turbine which makes for great reliability. Foundations are small and no boiler-house is required.

(6) The charging set has a maximum speed adjustment. If this maximum speed is exceeded the fuel is cut off.

This Velox governing gear is shown in more detail in Fig. 99. The amount of fuel and volume of air are so regulated that the steam pressure remains constant within the limits of sensitivity of the governing gear. To attain the desired result, the steam pressure in the outgoing steam pipe 1 works on the pressure regulator 3 through tube 2. In this pressure regulator, the steam pressure acts on a spring through the agency of a bellows device. The tension of this spring can be altered by handwheel within a wide range, and thus determines the steam pressure necessary to move it. If the steam pressure increases, the metal bellows opens an oil valve 4 so that oil pumped by pump 5 through pipe 6 and the throttle point 7 can flow off through the escape 8. The oil pressure then falls in pipe 9 leading to the fuel regulator 10 as well as in pipe 11 to the motor regulator 12. The piston of the fuel regulator sinks under the pressure of a spring thus closing the oil-fuel nozzle of burner 13. At the same time, the fall in oil pressure in pipe 11 causes the relay piston 43 of the motor regulator to be displaced which causes the regulating piston 14 to move, the latter adjusts the brushes of the regulator motor 15 in the sense of lower speed and output. The speed of the charging set is reduced and blower 16 gives less air to the combustion chamber of the evaporator, corresponding to the smaller quantity of fuel passing. The setting of the regulating brushes of the motor can be made dependent of the oil pressure in pipe 11 or finally of the volume of fuel in the combustion nozzle 13 by inserting a cam of the desired track or profile 17, which moves the external cylinder of the relay piston 13. The steam pressure regulator 3, therefore, dictates the steam pressure in the evaporator and the cam profile 17 determines the ratio of the mixture of fuel and air. At full load, the excess of air can be reduced up to about 10 %, without danger of incomplete combustion and smoke production in the evaporator.

The amount of water in the Velox is maintained constant by the water-level regulator 18 and the feed valve 19. The steam generator is kept continuously full by the circulation pump 20 so that a water level only appears in the steam separator 21. This water level acts on the membrane of the water-level regulator 18, along with a spring acting from below, while above the membrane there is a constant water column. The valve 23 only serves to shut off the

regulator from the Velox, the connection being such that a load on one side of the membrane only and the destruction thereof is impossible. When the water column sinks the membrane of the regulator moves down and closes the oil valve of the regulator. This causes the pressure in the pipe 25, supplied by pump 5 through throttle point 24 to rise and the pressure thus rises under the relay piston of the feed water regulator 19. The feed regulator opens the supply pipe coming from the preheater 26 and completes the water supply in the evaporator until the desired water level is attained. Motor 27 drives the fuel pump 28 which forces the oil into nozzle 13, through the preheating and filter set shown under 29. The apparatus 30 measures the water pressure generated by the circulation pump and opens contact 31 if the pressure or the circulating water supply fails. This stops motor 27 and the fuel supply to the Velox is cut off. The charging blower 16 is driven by the gas turbine 32 which is itself driven by exhaust gases from the combustion chamber. The speed of this set rises and falls with the load on the Velox. It must not, however, exceed a certain value and is protected by a safety regulator 33, for this reason. If the maximum speed admissible is exceeded, this safety regulator acts, opens an oil valve and lets the oil flow out of pipe 35 which is supplied by pump 5 through throttle point 34. This causes relief valve 36 to open and stops the turbine. At the same time, the oil pressure fails in pipe 9 owing to return valve 37 and this, in turn, causes the fuel regulator 10 to close nozzle 13 and stop the Velox. The Velox regulating gear works in exactly the same manner when the charging and pumping sets are driven by steam turbines and not by electric motors. This description shows that the regulation of the Velox generator can be made completely automatic thanks to a suitably studied oil regulation and that it is proof against trouble. No attendance is required.

When comparing a Velox steam generator to other competitive steam boilers the advantages of this completely automatic regulation should carry weight, as it is not to be found in other systems.

Up till to-day, *21 Velox steam generators and heat generators* for an average total steam output of 25 tons/h per unit are being built or are already working. The little space taken up by the Velox steam generator and the design of the Turbloc developed earlier by Brown Boveri have made it feasible — as far as oil and gas firing are concerned — to create a *completely novel design of steam power plant, the Velox Power Plant.* The steam generator, the turbine, the condenser and the auxiliaries form an enclosed and quite independent unit. As with Diesel engines, only fuel and cooling water will be led to this set and electric power and cooling water taken from it. All connections to neighbouring sets will be eliminated with the result that a plant of astoundingly simple layout is brought into being. Fig. 101 shows a Velox power plant, in plan and elevation (without switchboard or fuel container). A standard Velox is direct connected to its turbine without any of the usual complicated piping and without steam slide valve. Turbine, generator, and condenser form a block. The auxiliaries are divided into two groups of which one, at constant speed, comprises the pumps for lubricating and for governing oil, for fuel, for cooling water, for condensate, air and feed water, while the other group, at variable speed, comprises the gas turbine, the charging compressor and the auxiliary turbine. The first group is driven by the main machine through a patent arrangement of reduction gear which allows of lodging the pumps sufficiently deeply below the axis of the main set. The second group is driven by the gas turbine and by the auxiliary turbine and its speed and output varies according to the volume of steam generated. Starting up is done by driving the auxiliaries by electric motors through slip couplings. If the power station is to be independent, the starting-up current, for the first time, is supplied by a small set composed of a gasoline engine coupled to an electric generator. In order that the power required for starting should be small, starting up is carried out with reduced fuel and air supply, i. e. with auxiliaries running below the standard speed. By direct drive of the auxiliaries by the main machine and by using a turbine as auxiliary motor, a high degree of service reliability is ensured. As is known, the lubricating-oil pump has always been coupled to the main turbine so that the supply of oil may be assured under all circumstances, and, as is also known, nearly all big condensing-pump sets have a steam turbine as emergency spare besides the standard and economic electric drive of the set, this because experience has shown that the failure of current leaving auxiliaries without electric power may deprive whole town quarters of electric power. In the new Velox type of power plant all the auxiliaries and not only the oil pump are driven by the main turbine thus making it proof against serious trouble of this nature.

Owing to the elimination of a system of pipes with flanges and sluice valves, the Velox power station

or jet, principle which eliminates the disadvantages of the earlier types, and of others still built, to-day, by some firms. A section through the new *Brown Boveri electric boiler* is shown in Fig. 103. A circulating pump 1 draws water from the boiler and presses it through tube 2 into the ejection pipe 3. There are six rows of nozzles 4 in the upper part of this pipe out of which the water is ejected in sprays 5 impinging on the three electrodes 6. These have a patented shape, so that the water impinges tangentially on their inner surfaces and is so deflected that — without spraying — it acquires a circulative downward motion towards sieve 7.

Electric current is led in to the boiler through insulating bushings, travels through the water jets 5 and also through the water flowing downward and, thus, reaches the iron body of the boiler forming the earthed neutral point of the electric system. Regulation of the power input is very simple, being carried out by the opening or closing of the throttle valve regulating the flow of water, and therewith, the number of water jets in action and the jet resistance to the current. The throttle valve can be made to be controlled by a pressure regulator so that the steam pressure is maintained constant automatically or be made dependent on the amount of electric power available by operating it by an auxiliary motor controlled from the switchboard.

The supply of feed water is regulated automatically by means of a regulator dependent on the water level, which opens or closes the supply valve. In the Brown Boveri electric boiler, the water level can sink to a certain lower level without affecting the output, which is not the case with boilers having immersed electrodes. It is only when the water has sunk to such a level that the circulating pump cannot circulate any more water, that the output begins to go down. There is no danger due to want of water, in any case. Therefore, the Brown Boveri boiler can very well be supplied by hand.

The Brown Boveri electric boiler has the following advantages: — There are no resistance-carrying ceramic parts immersed in the boiler water, the bushing insulators being lodged in the highest part of the steam chamber. This obviates the necessity of changing these parts regularly, which happens with boiler water which contains soda, in which the said parts dissolve. Apart from the spindle of the rotary valve, there are no regulating rods or movable bushings through the boiler wall. In Brown Boveri boilers the resistance can be changed within wide limits by changing the number of water jets in action *so that the load can be regulated smoothly from full load down to no load.* In other boiler systems, the resistance cannot be increased sufficiently and they, therefore, only allow of a much narrower output regulation. A further, very advantageous quality in certain cases, is that the jet system can be built for a very high inner resistance and thus allows of using chemically purified water, so that sludge formation, which is unavoidable when impure water is used, can be guarded against to a great extent.

Figs. 104 and 105 show two electric jet boilers for the Dolder swimming bath (Zurich) and the Cima Chocolate Works, Dangio (Tessin). The first of these boilers is built for 800 kW, 6000 V at 2 kg/cm^2 abs with pump mounted outside. It delivers its steam to a heat exchanger or condenser seen in the background, where the heat is transmitted to the water used in the bath. The second boiler is built for 300 kW at 8000 V at 8 kg/cm^2 abs. Its circulating pump is inside the boiler, as the drawing of Fig. 105 shows. It can be dismantled, however, without difficulty, by loosening a flange.

(4) *Condensers and coolers.*

Feed-water supply equipments for power stations have been brought to a high degree of perfection by Brown Boveri and much valuable data on the

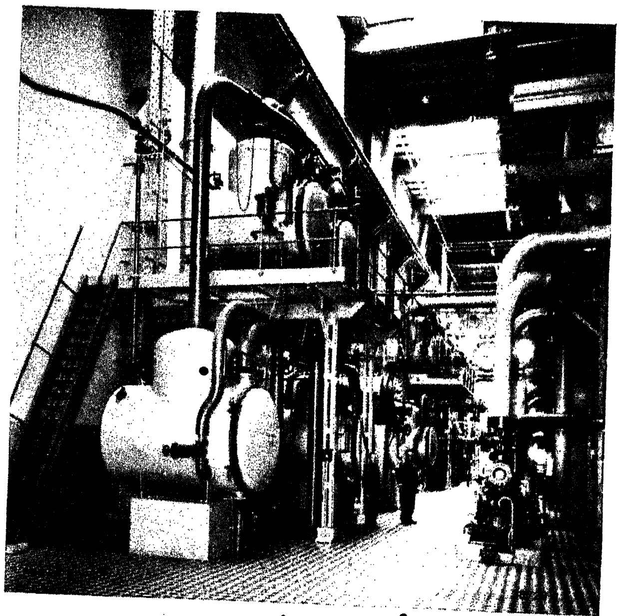


Fig. 106. — Feed-water, preheating and evaporating plant of the big Puerto Nuevo Power Station, Buenos Aires.
Brown Boveri has gained much experience in the study of feed-water supply of steam plants and in the building of equipment for condensation, preheating and evaporating plants.

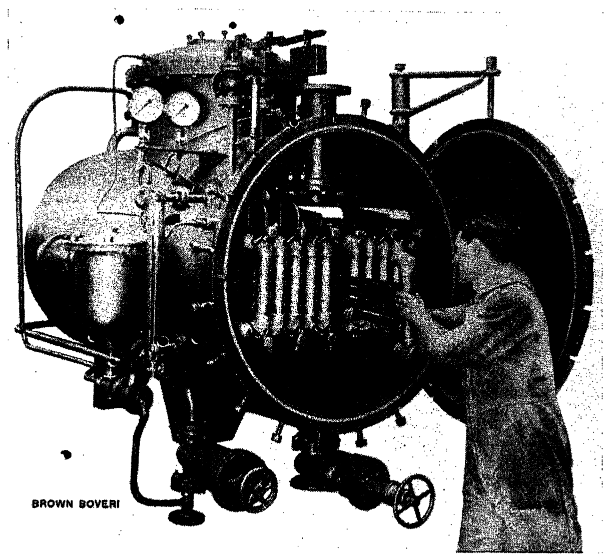


Fig. 107. — Raw-water evaporator.
These apparatus give a chemically pure distilled product. They are designed so as to be easy to clean.

subject has been collected. A big plant of this kind for a turbine output of $3 \times 30{,}000$ kW is illustrated in Fig. 106, which shows the feed-water preheater and evaporating plant in the big new power station Puerto Nuevo of the Cia. Italo Argentina, Buenos Aires. Fig. 107 shows one of the modern raw-water evaporators used there. The object of an apparatus of this type is to eliminate salts and impurities from the water which, of course, means that the apparatus itself gets very dirty. We have designed an evaporator which can be cleaned out, quickly and simply. Butterfly nuts hold down the cover which can, however, be quickly opened allowing of drawing out the then accessible stacks of tubes, so as to clean them from either side.

The *new coolers for air, steam and gases* are worthy of note as they have been developed to a high degree of efficiency. The basic element in these plants are the ribbed tubes, as shown in Fig. 108, which are built up by Brown Boveri according to their own process. A thin strip of sheeting is wound on edge round a brass tube of standard diameter. This strip is soldered to the tube without injury to the latter such as often occurs with other kinds of ribbed tubes. These tubes are grouped in standard stacks and held by frames, the stacks being placed in the line of gas flow without difficulty. Fig. 109 shows a tube stack of an air cooler for a generator which is characterized by its self-contained, compact design.

We also deliver all kinds of heat transmitting apparatus for air, gas, steam, water, oil refrigerating purposes, etc.

Brown Boveri has developed a *"tube-cleaning pistol"* based on the patent of a closely allied inventor. This interesting apparatus is intended for condensers and other tubular coolers. It goes under the name "Columbus". Fig. 110 shows the appearance of the apparatus and Fig. 111 gives a section thereof. The pistol is held by a handle and the cleaning body 2 secured to a steel ribbon 1 is introduced into the tube 3 to be cleaned. The mouth piece 4 closes off the tube from the outer air. By compressing, by finger, button 5, water under pressure is ejected from tube 6, over valve 7, into the tube to be cleaned

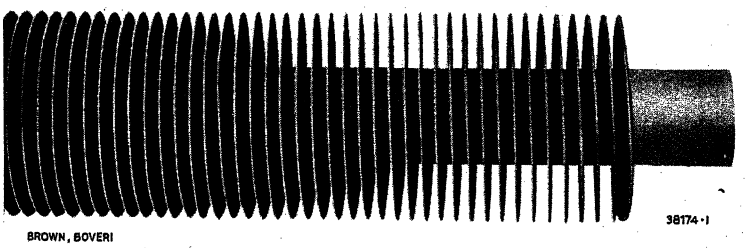


Fig. 108. — Brown Boveri ribbed tubing.
The cooling rib is laid on and soldered to the tube according to a special process and without injury to the tube.

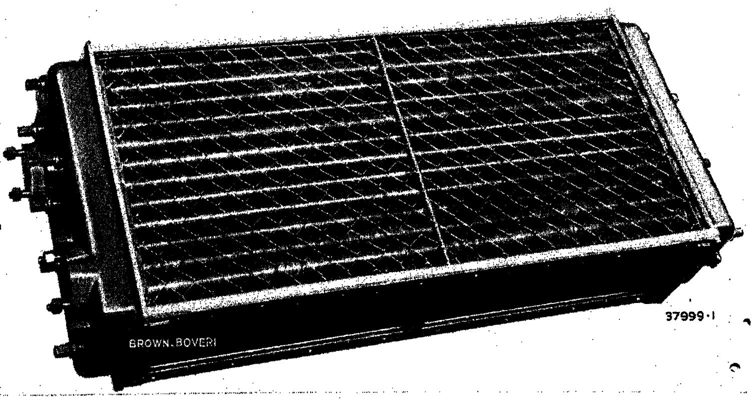
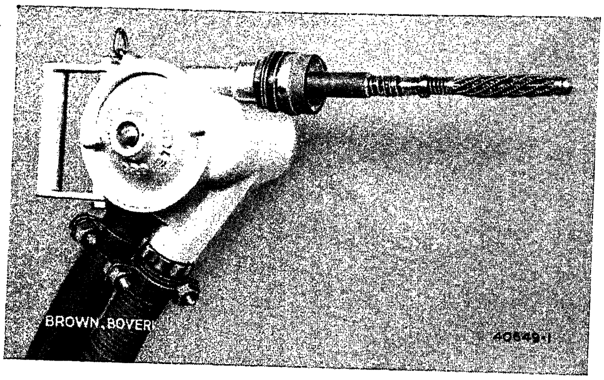


Fig. 109. — Stack of generator cooling tubes made of Brown Boveri ribbed tube.
The stack of tubes is delivered ready to be built in and requires no special design of the foundations to accommodate it.

and drives the cleaning body 2 at high velocity through the tube. After having passed through the length of the tube given, which can be adjusted for, a control valve 8 deflects the water under pressure on to a small turbine 9 which drives the steel ribbon



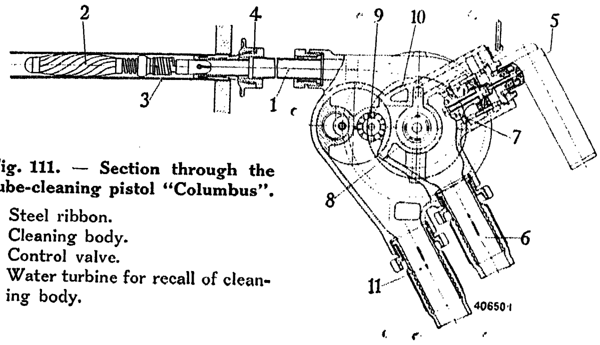


Fig. 111. — Section through the tube-cleaning pistol "Columbus".

1. Steel ribbon.
2. Cleaning body.
8. Control valve.
9. Water turbine for recall of cleaning body.

Fig. 110. — The tube-cleaning pistol "Columbus". The pistol projects the cleaning body through the condenser or cooling tube, by hydraulic pressure and then draws it back again automatically by the action of a small hydraulic turbine winding up a steel ribbon; it then goes on repeating the operation as long as the push-button is depressed.

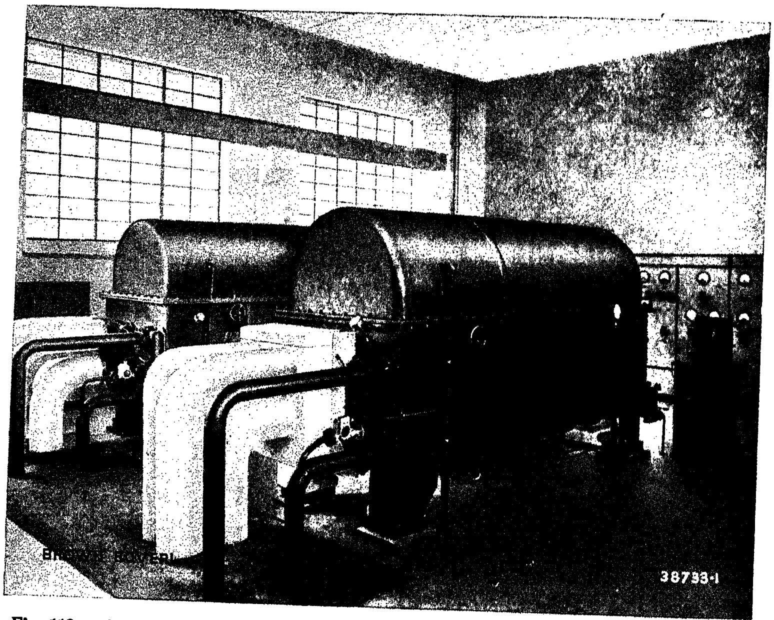


Fig. 112. — Two frigiblocs in the Helsingfors slaughter house, each for 300,000 kcal/hour.

roller 10 backwards, through a gear, thus recalling at high velocity the cleaning body 2 on the steel ribbon 1. As soon as the steel ribbon has been rolled up again, the control valve 8 deflects the water jet again and shoots the cleaning body through the tube once more. A tube 4 metres long can be thus traversed and the cleaning body wound up again in about 7 sec, the recall pull of the water turbine being about 15 kg for a water pressure of 8 kg/cm^2. According to the kind of foreign matter to be removed from the tube, the cleaning body is given more or less radial tension and is either passed once or several times through the tube. The Columbus pistol, thus, eliminates cleaning rods and saves the space they take up, essential factors with other methods of tube cleaning. In big condensers, the Columbus pistol can even be placed inside the water chamber so that, with the exception of the man-hole, it is not necessary to take off the cover. This apparatus simplifies and accelerates condenser cleaning.

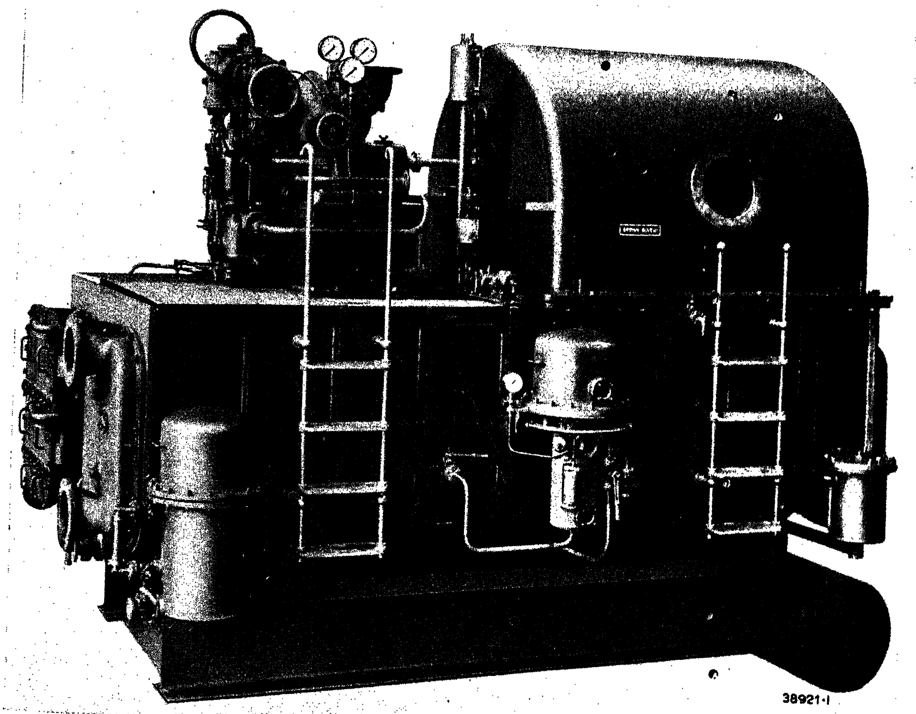


Fig. 113. — Frigibloc driven by steam turbine, for Kodak-Pathé S. A., Vincennes, for 600,000 kcal/hour.

Apart from the steam turbine, the compressor, condenser, evaporator and all auxiliaries are gas-tight enclosed in the bloc. The driving shaft passes through an oil-sealed gland.

Condensers are now cleaned more frequently, as cleaning is easier to carry out and they consequently work under a better average vacuum. This, in turn, means saving in fuel. We are expecting a big sale of these practical instruments.

(5) *Refrigerating plants.*

Thanks to its small size, light weight, simplicity of design and attendance the Brown Boveri *Frigibloc,* a refrigerating turbo-compressor, forming with its condenser and evaporator a completely enclosed unit, has found new fields of application. Fig. 112

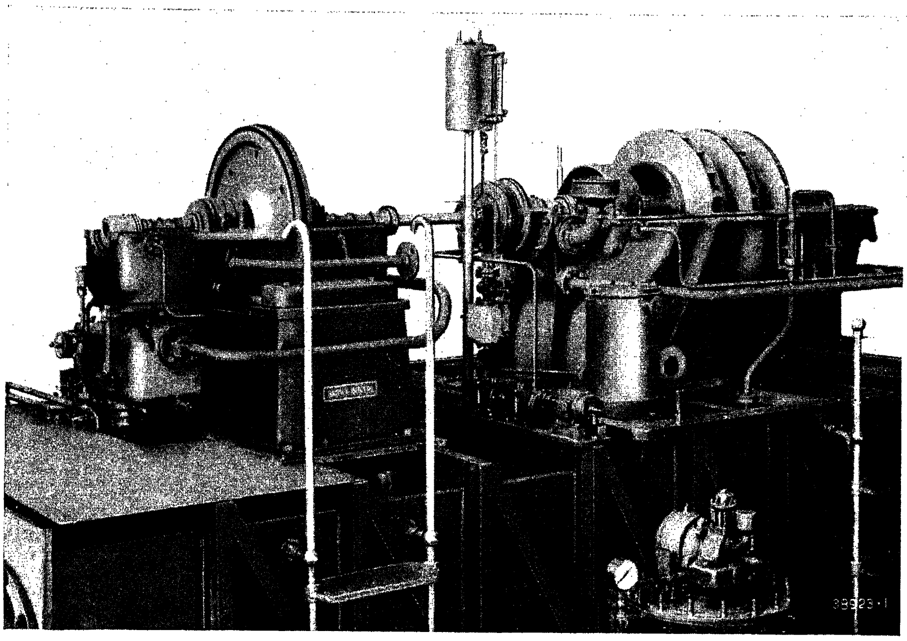


Fig. 114. — Steam-turbine-driven Frigibloc, cover raised.

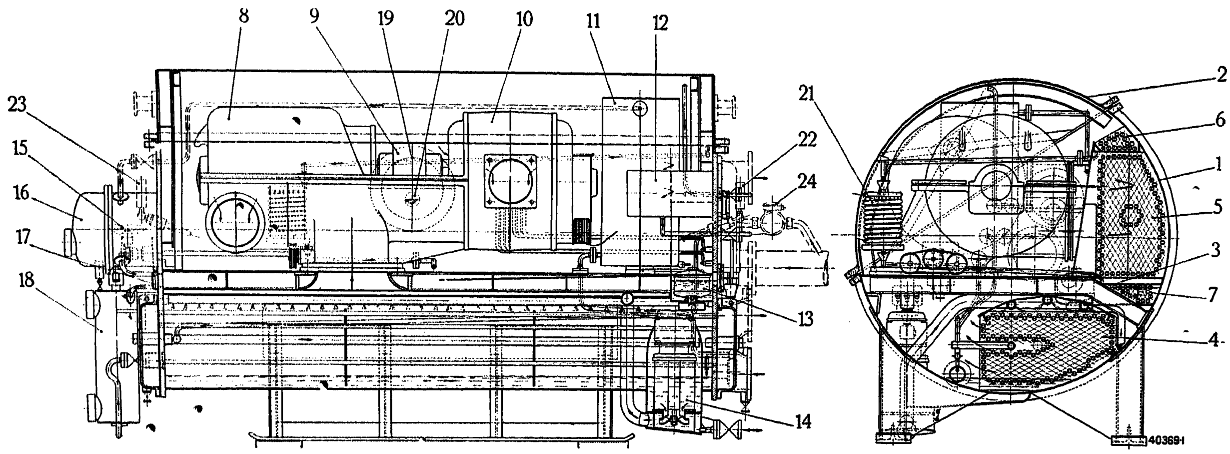


Fig. 115. — Section of 1935 model of the Frigibloc. The bloc is round in shape, the cover being placed aslant so that it can be slid off, sidewise, over guide rails, without requiring additional erection head room.

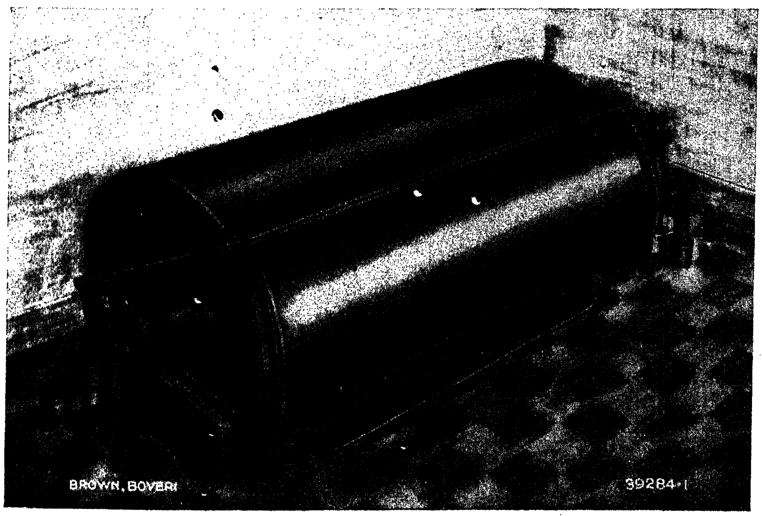


Fig. 116. — Outside view of 1935 model of the Frigibloc.

shows two Frigiblocs which have been running for two years in the Helsingfors slaughter house, each of which has a refrigerating capacity of 300,000 kcal/hour. Figs. 113 and 114 show a steam-turbine driven Frigibloc in a plant belonging to *Kodak-Pathé S. A., Usine de Vincennes,* built for 600,000 kcal/hour. In this case, as well, the compressor, evaporator, condenser and all accessories are gas-tight enclosed.

The drive by the turbine, from outside, is through a shaft carefully sealed by oil. The packing gland shaft is cradled on its own bearings and flexible coupled

on both ends, so that it is independent of all movements of the turbine and compressor. This allows of reducing the loss of oil from the gland to a few drops per hour. Two tiny pumps bring back to the container whatever oil has seeped inside or outside.

The Frigibloc has been further perfected, its weight reduced, its design and attendance simplified while the outside lines have been modified so that it can be more easily mounted. Fig. 115 gives a section of the 1935 model and Fig. 116 an outside view. The most striking feature is that the outside casing is now circular; all stiffening ribs are eliminated, the housing is simple and light. The cover is fitted aslant, and is displaced sideways over built-in guides. This design decreases the headroom requisite to erection without making the machine broader. The heat condenser is above and on one side and the cold evaporator is lodged below which reduces the heat transmission. When at rest, the Bloc empties down into the evaporator preventing freezing of the cooling water in the condenser due to faulty attendance when the machine is stopped. For overhauling, the whole refrigerating plant can be emptied and refilled again from one point. The Bloc rests on sliding soles on which it can be rolled, completely assembled, to the site of erection.

The Frigibloc has many advantages. The whole plant is enclosed in a gas-tight housing. Apart from the pipes for carrying off water and brine and the electric conductors, the Brown Boveri refrigerating plant has no apparatus, conductors, flanges, valves, containers, etc. Erection work is limited to connecting up cooling water and brine pipes and electric conductors. One of the great advantages of the Frigibloc as compared to other refrigerating plants is the use of a turbo compressor instead of a reciprocating one. All frictional parts, with the exception of the bearings, are thus eliminated and there is not wearing down or lubrication of similar organs. No oil is circulated along with the refrigerating gas, to get deposited on the surfaces of condenser and evaporator. The Frigibloc does not require much power to drive it, as every part is built in and there are no heat or pressure losses in long connecting pipes.

The space taken up by the Bloc is so small that no machine hall is required for it. Like a domestic refrigerating plant, the Frigibloc can be run automatically, without attendance; the Frigibloc is quite enclosed and, therefore, runs noiselessly and all these qualities make it suitable for industrial plants and especially so for air-conditioning plants, theatres, hotels, business buildings as well as for plants overseas where skilled operators are not available. Above all, it is suitable to marine plants owing to the small space it takes up and to its enclosed design. The basic principle and details of the Frigibloc are patented.

(6) *Turbo-compressors and blowers.*

The Brown Boveri-Büchi *charging process*, to increase the output of four-cycle Diesel engines, has been considerably improved. 24 Diesel-engine manufacturers, among which the most important concerns, are using the charging process and there are more than 200 Diesel engines working to this process to-day and producing a total of 435,000 H. P. The fuel consumption of the Diesel engine has been brought down by improving the efficiency of the exhaust-gas turbine and of the charging blower, by perfecting the gas and air ducts as regards dimensions and lay out, by improvement of the Diesel engine governing gear and by building on the charging set close to the engine. These improvements have allowed of extending the field of application of this process to small, fast-running Diesel units down to about 150 H. P. It must be admitted that the charging of such small Diesel

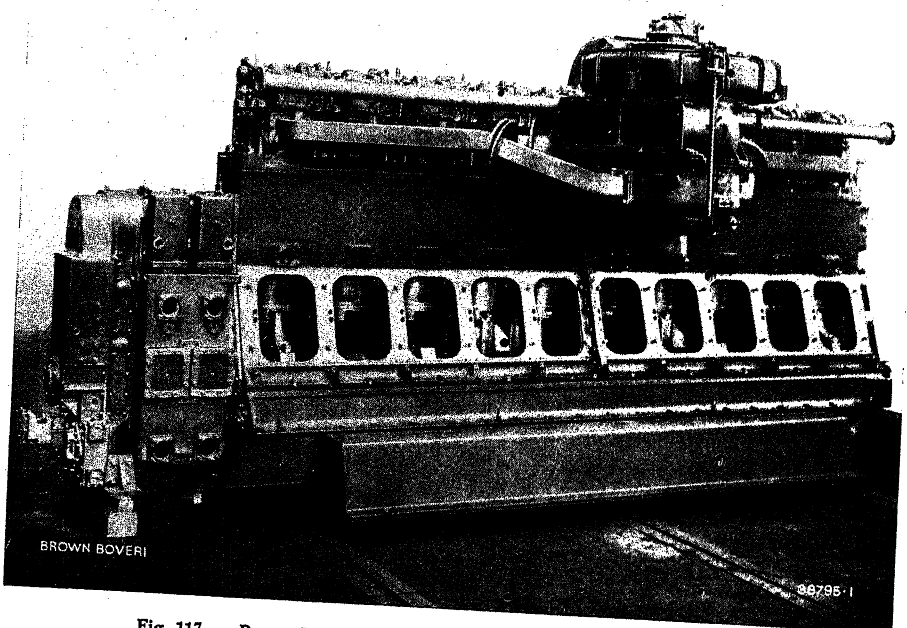
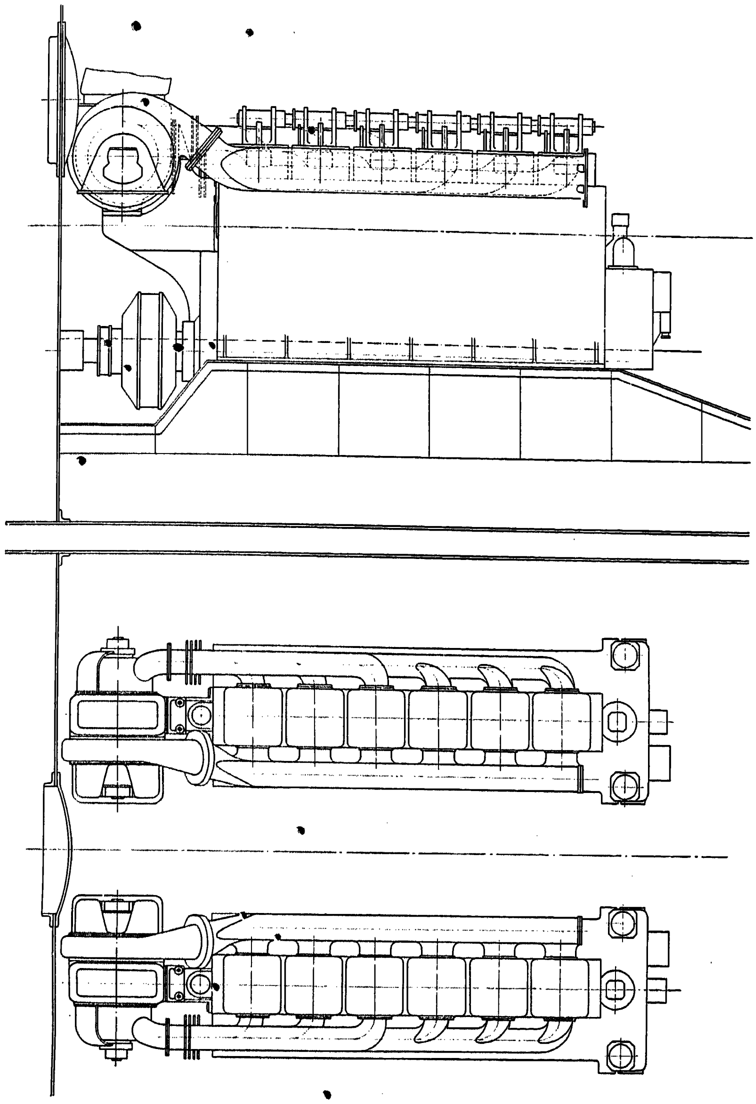


Fig. 117. — Brown Boveri-Büchi charging set on an MAN Diesel engine.
20 of these sets were delivered to the Mexican navy. The engine output is increased by charging from 1150 to 1700 H.P.



engines does not cheapen the price of the engine, but it is a welcome innovation as it lowers the weight per H.P., decreases the bulk, gives better fuel consumption, causes less heat stressing, deadens the noise made by the exhaust gases, leads to quieter running and makes the Diesel engine astonishingly flexible in service. "Charging acts like balm on the Diesel engine" or "The Diesel engine runs as though asleep" are tributes paid by operators who have learnt to know the advantages of charging. For vehicles, ship engines and those for motor coaches, the charging process has special significance, as it means less weight. We have definite expectations of being in a position, very shortly, to apply charging to the automobile engine. In the course of last year, orders were booked for 20 charging sets for Diesel motor coaches and locomotives by Messrs. Maybach, by MAN, by Deutz and Daimler-Benz, besides 31 similar sets for high-speed marine Diesel engines. Of these 20 charging sets for MAN engines are for revenue cruisers of the Mexican navy. Fig. 117 shows one of the latter MAN engines with built-on blower. The engine rotates at 700 r.p.m. and, thanks to the charging process, it was possible to increase its output from 1150 H. P. to 1700 H. P. Fig. 119 shows a modern charging blower in which the four rest points can be made to fit any Diesel engine design and in which dismantling does not require any pipes being loosened. Fig. 118 shows two high-speed Diesel engines with charging sets mounted in a submarine.

The charging process is especially suitable to this purpose as more importance is attached here to light weight, small overall dimensions, low oil consumption and smooth running than in any other Diesel application. The smallest charging set built up till now is shown in Fig. 121 and, in Fig. 120, built on to the Diesel. This charging set is used for raising the output of a 150-H.P. engine to 230 H.P. The curve sheets given in Fig. 122 are the results of tests with 6 Diesel engines built by MAN, SLM, Deutz and one other firm, all with charging sets. These curves all prove the advantages which accrue from using charged engines.

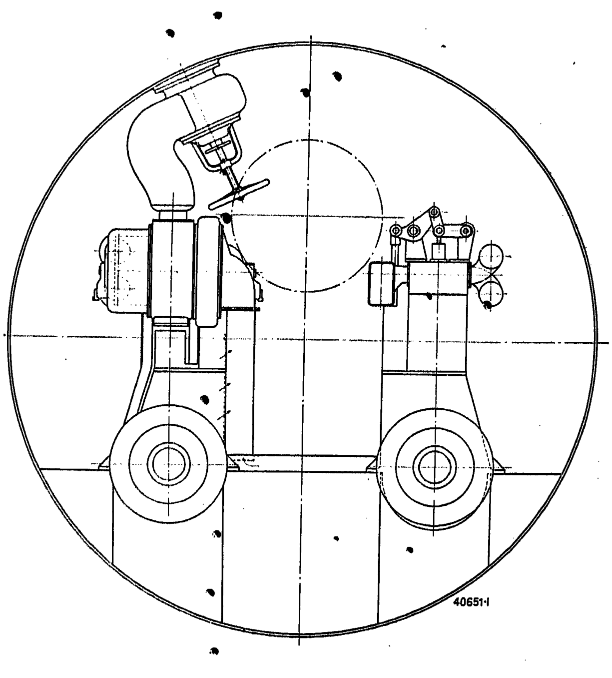


Fig. 118. — Mounting of four-stroke Diesel engines with Brown Boveri charging sets on a submarine.

The charging sets increase the engine output by 50 to 60 % without, practically increasing the space taken up by the engines.

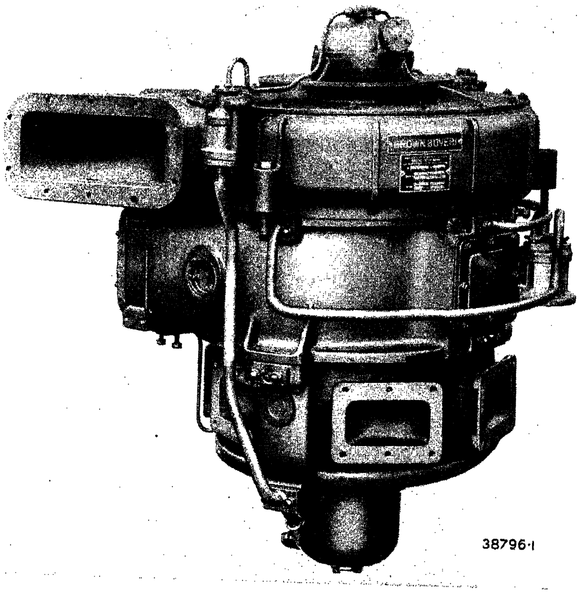


Fig. 119. — Latest design of Brown Boveri charging set.
The four supports of the gas turbine and blower can be made to suit any engine, without any difficulty.

(7) *Marine drives and auxiliaries.*

Last year, we mentioned here that we had secured the order for two Velox steam generators of 18 and 45 t of steam per hour intended for marine purposes and we are now able to state that the British and another important Admiralty have decided to give the Velox a trial. The orders are for units of 50—55 tons per hour of steam, a type which would appear to be about standard for torpedo-boat destroyers. The boiler for the British Admiralty is being built in collaboration with Messrs. Yarrow & Co., Glasgow and our British concessionaries, Messrs. Richardsons Westgarth & Co., Hartlepool. The Velox steam generator has very many advantages for warships as it takes up little room and can develop a very large volume of steam per unit of weight, at high efficiency.

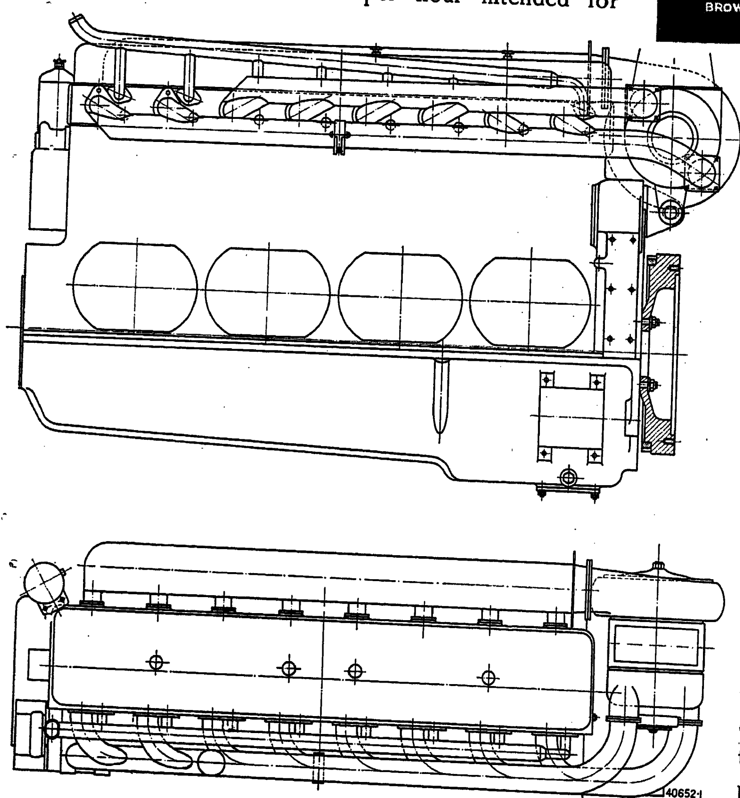


Fig. 120. — High-speed traction Diesel engine with built-on charging set.
By bringing the engine and the charging set as close together as possible, the effect of charging is enhanced; extra space is hardly necessary.

Fig. 121. — Smallest charging set built up to date.
This set charges a traction Diesel engine and increases its output from 150 to 230 H. P.

The water-tube boilers used, to-day, on warships have been developed up to the limit of their capacity. Boilers which produce continuously 25—30 kg of steam per hour and per m^2 in merchant ships are forced up to 100 kg per m^2, in an emergency, in warships. These overloads can only be kept up for a short time, however, as the temperatures

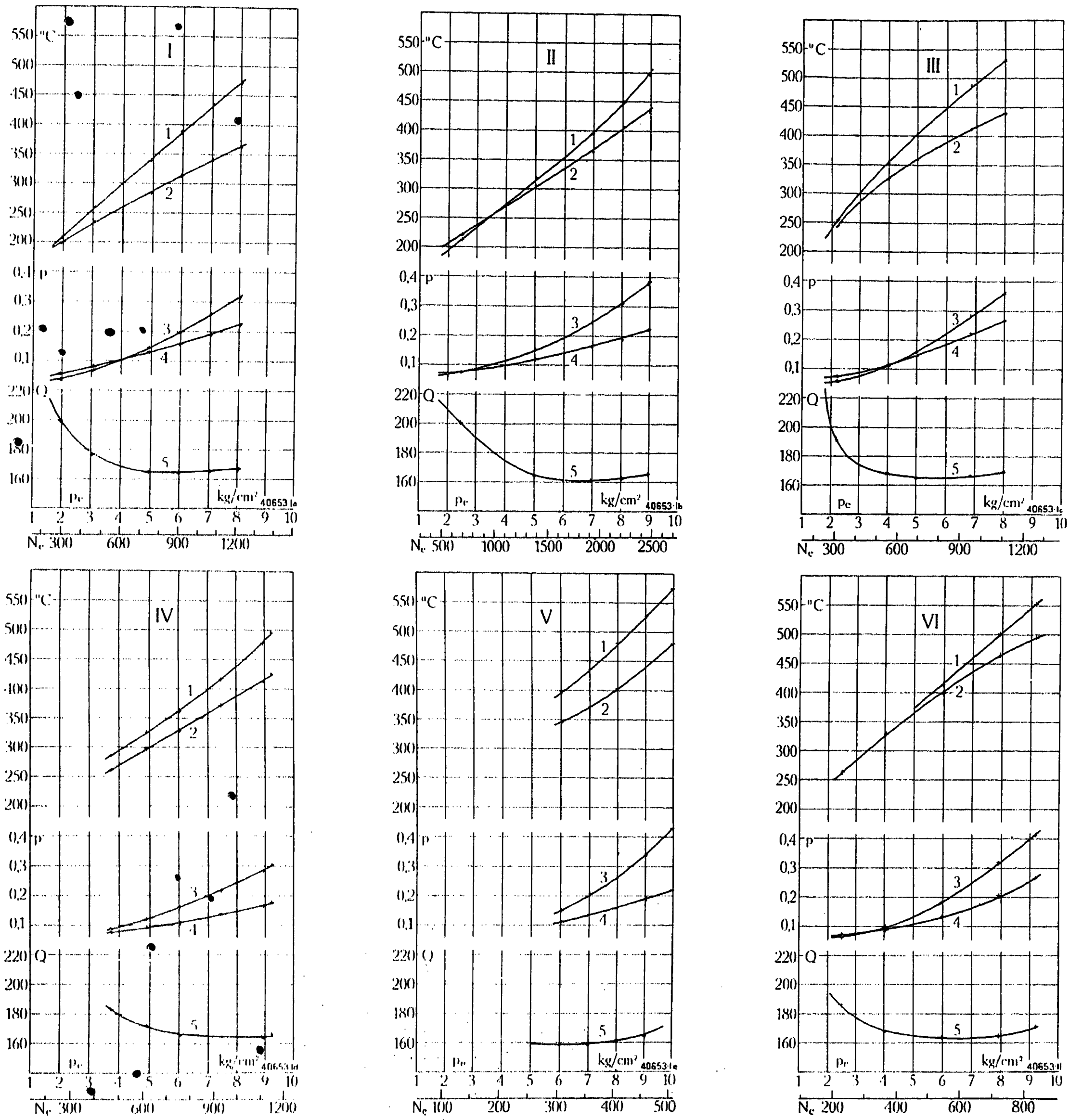


Fig. 122. — Test results from six four-stroke Diesel engines of different firms with power increased by the Büchi process with Brown Boveri charging sets.

The test curves all reveal the excellent results of charging.

Units:—
- p. Pressure in kg/cm².
- Q. Fuel weight in g. per effective brake H. P. and per hour.
- p_e. Average eff. pressure in kg/cm².
- N_e. Brake output in eff. H.P.

Curves:—
1. Exhaust-gas temperature before turbine.
2. Exhaust-gas temperature after engine valves.
3. Charging pressure of air.
4. Exhaust-gas pressure before turbine.
5. Fuel consumption of engine.

Test results on Diesel engines with exhaust-gas turbine-driven charging sets of the Brown Boveri-Büchi system.

Slow-running machines.

I. **Plant Bizerte (Tunis).**
Engine by the Swiss Locomotive and Machine Works, Winterthur.
Trunk-piston engine without compressor 8 × 390/520 r. p. m. = 273.
785 B. H. P. without charging.
1000 B. H. P. with charging.

II. **Plant Misz (Egypt).**
Engine by the Maschinenfabrik Augsburg-Nürnberg, Augsburg.
Trunk-piston engine without compressor, 6 × 580/840 r. p. m = 187.
1575 B. H. P. without charging.
2250 B. H. P. with charging.

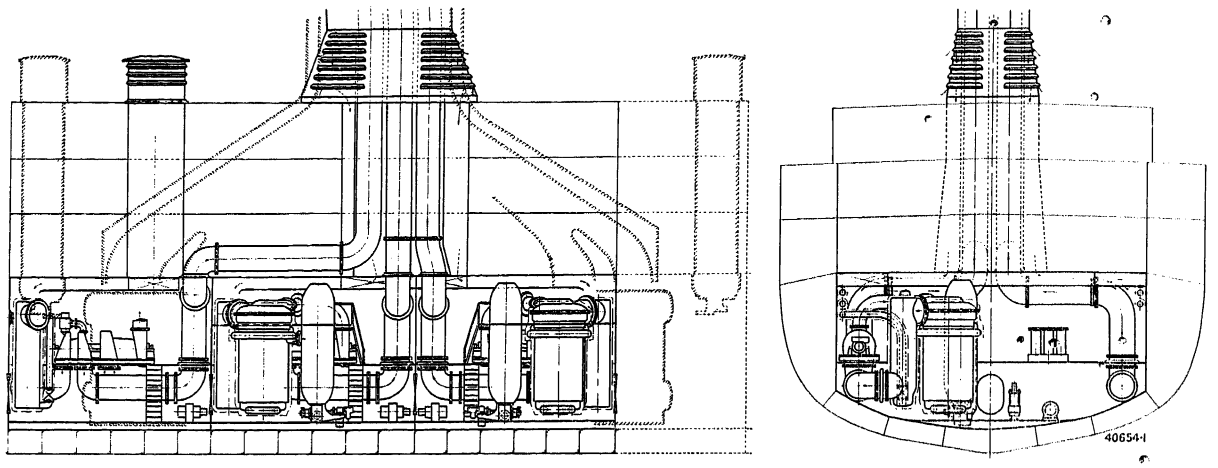
III. **Plant Toowoomba (Australia).**
Engine by Humboldt-Deutz Motoren A. G., Cologne.
Trunk-piston engine without compressor, 6 × 400/600 r. p. m. = 250.
750 B. H. P. without charging.
1000 B. H. P. with charging.

Fast-running machines.

IV. **Test engine** by Maschinenfabrik Augsburg-Nürnberg, Augsburg.
Trunk-piston engine without compressor 6 × 300/380 r. p. m. = 700.
690 B. H. P. without charging.
1050 B. H. P. with charging.

V. **Test plant** of another firm.
Trunk-piston engine without compressor 6 × 220/320 r. p. m. = 625.
280 B. H. P. without charging.
420 B. H. P. with charging.

VI. **Test plant** of Swiss Locomotive and Machine Works, Winterthur.
Trunk-piston engine without compressor 260/320 r. p. m. = 800.
455 B. H. P. without charging.
750 B. H. P. with charging.



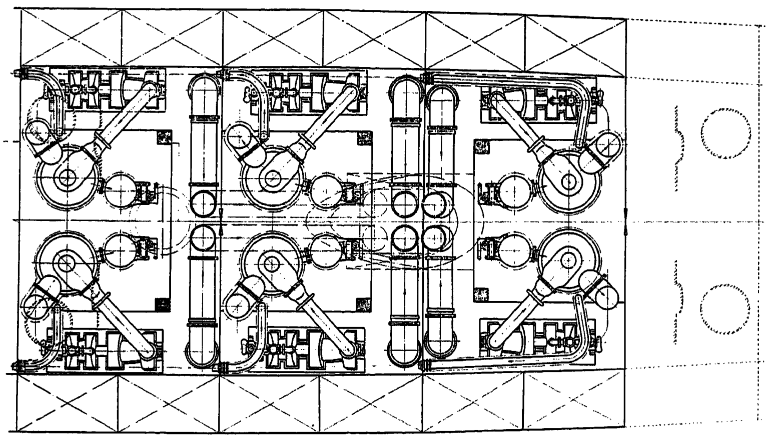


Fig. 123. — 2 Velox steam generators on a warship when compared to the design with a water-tube boiler plant of the same capacity.

Points of interest are the small section of the apertures which it is necessary to make in the armoured deck and the small sections of the exhaust gas ducts.

of the exhaust gases rises to 450—500 °C and the efficiency, without auxiliaries, falls to as low as 70 %. The weight of such a water-tube boiler for a warship, as referred to this forced output, including water, fans, pumps, preheater, smoke trap and the pipes for air, water, steam and oil is only 1 kg per kg of steam generated. Now a Velox steam generating plant, contrary to the water-tube boiler, can carry the high steam production demanded continuously and this at an efficiency (all auxiliaries included) of about 90 %.

The weight of a Velox plant for 50 t/h of steam ready to operate, is less than that of the water-tube boiler even under overload conditions, despite the good economic utilization made by the Velox of the heat generated, while the higher efficiency of the Velox means a saving in weight of fuel oil or an increase in the radius of action of the vessel.

The space taken up by the Velox steam generator is smaller than that of an ordinary boiler on a warship; this fact, however, is not so apparent in the case of warships as in merchant ships as the water-tube boilers are heavily forced on the former.

Apart from the advantages enumerated, which can be expressed in figures, the Velox has other big advantages of a more indirect nature. The rapidity with which steam can be got up and the rapid manœuvring qualities imparted by the Velox — about 30 seconds from no-load to full load — are properties of vital importance to warships. The high velocity the gases allows of small sections for the exhaust-gas ducts and this means that only small areas of the armoured deck need be broken; the armoured belt protection of the boiler plant is more complete. As the boiler plant is shorter, the armoured belt can also be shortened. Big savings in space and weight can be effected in the exhaust-gas ducts and their insulation above the armoured deck, this on account of the smaller sections and lower exhaust gas temperatures, Fig. 123. On account of the danger of the boiler room getting filled with gas, in case of a gas attack, it is a great advantage that the Velox can work completely automatically, that is to say with a few or, in an emergency, without any boiler-house operators at all. The temperatures in the funnels of only 150-180 ° C improves visibility, both as regards gunnery and navigation.

It will be interesting to note that the use of the Velox steam generator on submarines is being thoroughly studied and that great possibilities seem to lie in this direction.

(8) *Materials.*

When discussing, last year, the *behaviour of our steels under constant load and high temperatures* and in publishing the results of a first series of tests under prolonged loading, we came to the conclusion that when material was stressed up to the neighbourhood

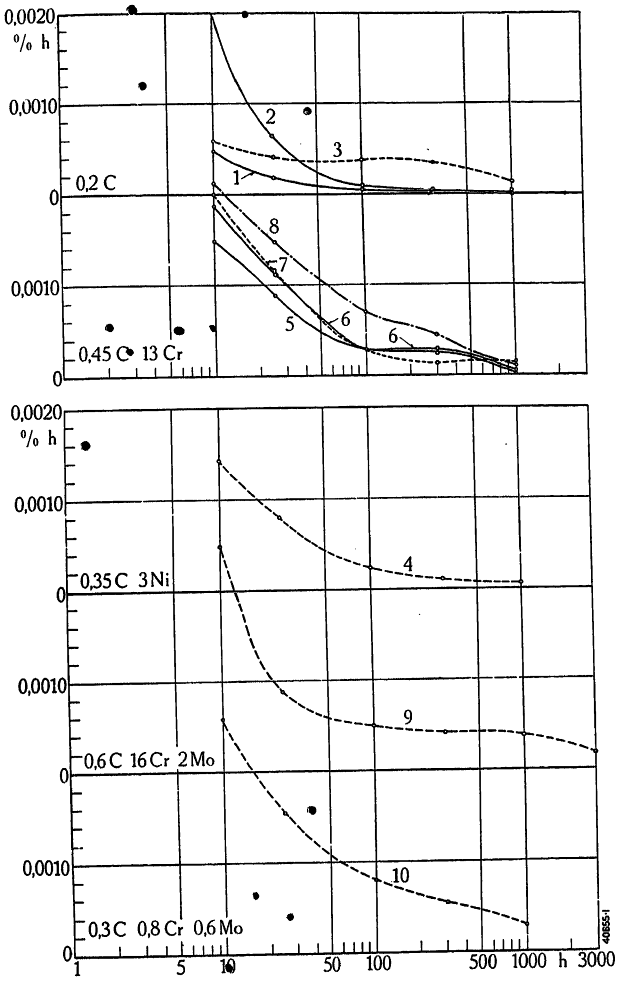


Fig. 124. – Creeping speed of structural steels under high temperatures. Results of tests made in the Brown Boveri metallurgical laboratories.

The tests showed that the creeping speed of steels under load quickly diminishes in the neighbourhood of the creep limit, in all cases. There is no danger of rupture for steels loaded slightly below the creep limit. These creep-limit tests as well as practical experience with hundreds of steam and gas turbines show that there is no danger of inadmissible deformation when the material is loaded up to about 70 % of its creep limit. There is a multiple factor of safety against rupture here.

SUMMARY OF TEST RESULTS.

Steel	Curve No.	Temperature in °C	Ultimate strength under tensile strength test of short duration kg/mm²	Creep limit kg/mm²	Load of test	Creep in % after 1000 hours
0·2 C	1	400	24	22	20	0·09
	2	400	24	22	22	0·05
	3	500	21	11	10	0·31
0·35 C 3 Ni	4	500	29	5	4	0·16
0·45 C 13 Cr	5	400	42	28	25	0·20
	6	400	42	28	28	0·14
	7	500	36	10	8	0·20
	8	600	22	25	2	0·40
0·6 C 16 Cr 2 Mo	9	500	41	40	35	0·34
0·3 C 0·8 Cr 0·6 Mo	10	500	50	14	12	0·54

of its strength against prolonged loading, termed the creep limit, it presents a multiple factor of safety as regards rupture; the strength against prolonged loading or creep limit being defined as the load under which the creeping speed measured between the 1000th and the 2000th minute of the test is $^{1}/_{1000}$ % of the length of the piece tested, per hour. We said that it sufficed to remain about 30 % below the creep limit in order that the deformation should remain within limits quite allowable practically. The rules suggested by some experts demanding a multiple factor of safety as regards the creep limit were explained to be not only superfluous but to lead to unnecessarily thick walls subject to more numerous and dangerous tensions due to too great differences of temperature.

To continue our last year's comments on this subject, we desire to give here some further results on duration tests (creeping phenomena) carried out by our metallurgical laboratory. A detailed report thereon will be published by the laboratory when the tests are concluded. Different kinds of steel under different temperatures and various loads were observed for 1000 hours and, in exceptional cases, for 3000 hours. The nature of such tests demands a great deal of time and great technical care and exactitude, so that there is yet little printed matter available on the subject. We think that the publishing of the results of our own measurements will be a contribution to the available data on the strength of constructional steels under high temperatures.

Fig. 124 with table belonging to it gives the speeds of elongation in function of time at different temperatures, in which tests the loads applied are those corresponding to the creep limit of the different steels or just above or below that strength. The tests are not numerous enough yet to allow of a definite statement on the behaviour of the steels under high temperatures, but certain deductions may, nevertheless, be drawn from the tests already made:—

(1) The creeping speed decreases very rapidly with all the steels under observation which are loaded up to their creep limit, or more lightly, this speed approaches zero in most cases after about 1000 hours. No test revealed an increase of the creeping speed or a rupture under loads in the neighbourhood of the creep limit.

(2) Under a stress 10 to 20 % below the creep limit, the speed of elongation is only a fraction of what it is under that corresponding to the creep limit.

(3) The steels designated as being impervious to heat have a greater creep limit but the drop in their creeping speed is slower than with steels less impervious to high temperatures. With these steels, as well, the creeping speed under stressing

in the neighbourhood of the creep limit also falls continuously but only approaches zero after several thousands of hours.

(4) A strand of steel stressed under high temperature elongates relatively much during the first 500 to 1000 hours. The designer must ascertain, in each separate case, what the amount of the possible deformation is and as to whether these deformations are admissible in the case of the structure considered.

A machine element is calculated for the highest stresses and temperatures encountered. But these, generally, appear at rare intervals and for short periods, say during the maximum overloading of a machine. The time during which creeping takes place is, thus, so short that even after years of service no deleterious deformation has appeared. Further, the highest stressing generally takes place in a very few points and extend over very short lengths of the structure and, often, the high temperatures and the big stressing do not take place at the same spots and at the same time. Thus, for example, a steam turbine blade is only stressed at its root, a disc on its hub that is over a short length only. In a pipe flange, the high temperatures are only felt on the inside while the highly stressed strands are outside round the base of the flange, that is, in a region where lower temperatures are encountered. It also happens that a few highly stressed strands situated, for example, on the outside of a bent rod or on the circumference of a hole made in a disc, stretch a little and distribute their load among the less highly stressed parts and thus relieve themselves of part of their load. The result of all the phenomena enumerated above is that, if the stressing on the most highly stressed parts is 30 % below the creep limit, as is admitted by us, the deformations which the whole structures are subject to are very small. The experience gained by our firm shows that when putting to practical use the results of the tests on strength against prolonged loading and when applying the stressing we consider as admissible, no deleterious deformations or service trouble due to material creeping arise. Brown Boveri has built about 300 steam turbines with temperatures of 400 to 485 ° C and about 200 exhaust-gas turbines for Diesel engines and Velox steam generators, for 500 to 550 ° C, and the perfect operation of these units justifies the conclusions just enumerated.

We repeat that when a structure is stressed slightly below its creep limit there already exists a multiple factor of safety against rupture and that no troublesome deformation occurs with suitably studied designs. The demand for a multiple factor of safety as regards the creep limit as specified by some bodies

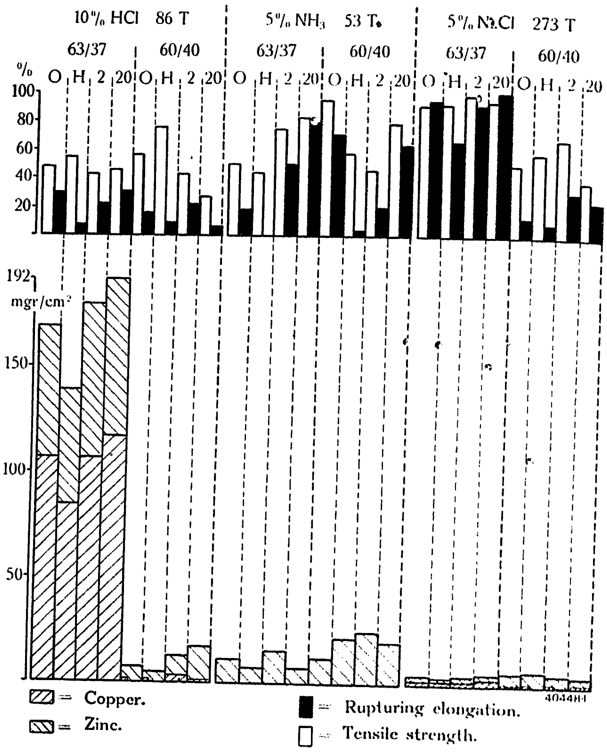


Fig. 125. — Corrosion of copper-zinc alloys. Results of tests made in the Brown Boveri metallurgical laboratories.

According to these tests, the quality of condenser tubes does not depend on the alloy they are made of, as long as the texture is uniform and there are no cold-treatment tensions in the metal.

O. Soft annealed; H. Hard drawn; 2·2 % cold hardened and recrystallized; 20·20 % cold hardened and recrystallized.

is unnecessary and may even prove dangerous when it leads to too thick walls, too great temperature differences and heat stressing.

We think it will be of interest to recall, here, the important results reached by our laboratories in their tests on the *resistance to corrosion offered by copper-zinc alloys,* with special reference to the alloys used for condenser tubes. These tests were made on condenser tubing of different alloys each one of which was examined in different conditions of heat-treatment and in various corrosive solutions. The alloys tested were:—

70 % Cu 30 % Zn, pure α phase structure
63 % Cu 37 % Zn, pure α phase structure
60 % Cu 40 % Zn, $\alpha + \beta$ phase structure
52 % Cu 48 % Zn, pure β phase structure.

The heat-treatment conditions were:—

Soft annealed
Hard drawn
2 % cold worked and recrystallized
20 % cold worked and recrystallized

The corrosive solutions in which the tubes were placed were:—

10 % HCl for a duration of 86 days
5 % NH_3 for a duration of 53 days
5 % Na Cl for a duration of 273 days.

Fig. 125 gives, graphically, the most important test results and the following important facts can be deduced therefrom.

(1) With the pure α or pure β phases, the corrosion is independent of the composition of the alloy. Dissolution is regular and, for the different pieces tested, it is in proportion to the component ratio of the alloy treated (i. e. without any predisposition of one or other of the two components of the alloy). There is little dissolution in the waters usually met with in practice and the material retains its resistant qualities. In markedly active dissolvents (acids), the dissolution and loss of resistant qualities are much greater.

(2) In alloys in which, owing to the choice of the alloy or owing to wrong thermal treatment, α and β crystals are contained, corrosion takes the form of a dissolution of the zink component, due to the state of constraint of the β crystals, accompanied by the formation of a very brittle porous structure of the material.

(3) Alloys having cold-hardening tensions loose their malleability even in mild dissolvents and are often destroyed by corrosive solutions. If the said cold-hardening tensions are only present in parts, corrosion may be localized to these parts or to spots.

(4) The size of grain plays no part in corrosion by liquids met with in practise but in stronger dissolvent the large grain crystals are more liable to attack.

According to the above tests, the quality of a condenser tube is independent of the alloy, in so far as the structure is uniform and there are no cold-hardening tensions. Uniform structure is itself easily attainable with an alloy of 70 Cu and 30 Zn. Alloys with less copper, down to 62 % of copper, can be used but, then, a correct thermal treatment of the tube, determined by the constitutional diagram, is necessary. The condition that cold-treatment tensions must be eliminated, calls for a careful heat treatment of every kind of alloy. Tubes which are sealed in the condenser end plates by packing glands must be hard in order to prevent denting on the inside and for this reason these tubes are liable to suffer from cold-treatment tensions and the results thereof. The safest tubes are those soft annealed and with both ends rolled into the condenser end plates. Here the Brown Boveri patented condenser design should be used with S shaped, curved tubes to prevent excessive tensions when differences of temperature arise between the condenser mantle and the tubes proper. The rolled in tubes are the best safeguard against infiltration of cooling water into the feed-water system.

III. THE WORK OF THE RESEARCH DEPARTMENTS.

We have to report, here, on two interesting research studies on the physical phenomena inherent to electric valves.

Recent scientific papers have expressed the opinion that quite thick vacuum containers, made of steel and cooled externally by water, were permeable to the hydrogen ions present, in more or less great numbers, in the cooling water. This assumption seemed to us, erroneous, from the first, as it was in direct contradiction to our own practical experience gained with more than 2000 water-cooled mutators, and we, therefore, carried out the tests which are described herewith.

The scientific articles, just mentioned and with the conclusions of which we did not agree, reported the following test:—

A quantity of diffused hydrogen amounting to $0{\cdot}277 \dfrac{\mathrm{cm^3 \cdot mm\ Hg}}{\mathrm{cm^2 \cdot h}}$ was found present in a seamless steel tube of 5 mm wall thickness, of usual commercial quality, immersed in distilled water at 95 ^{0} C. This hydrogen was put forward as being a dangerous cause of back firing in power mutators, because, when the arc is in operation, the electrodes are said to attract the hydrogen penetrating through the steel wall of the chamber and to release it again during the time the anodes are blocked. We intend to show, here, that experience gained by us on many water-cooled mutators leads to a quite different conception of what takes place, firstly, because the diffusion of hydrogen in the usual waters used for cooling purposes is negligeably small and, secondly, because hydrogen penetrates the electrodes during the dangerous blocking periods and not when the arc is burning. It is, further, not clear why other gases and vapours (Hg vapour) present in the arc chamber and which penetrate the anodes, under the form of ions, in very small quantities during the blocking period, should not be just as dangerous as the hydrogen ions. Experience, however, proves incontrovertibly that this is not the case because back firing is not a factor which disturbs the operation of modern mutators, being of very rare occurrence and being extinguished at once by controlled grids, if it does happen to occur.

It is, thus, in no way necessary to use other and less practical cooling mediums than water in order to avoid the very scarce back fires which arise and can be brought about by quite other causes. Of course, the water must not be too rich on ions, but

this not on account of back firing but because of the danger of corrosion of the metal piping through which the water is brought in.

We have fixed the following figures relative to the diffusion of hydrogen through steel walls.

(1) *Mutator built of steel with mercury sealings.* Volume: 300,000 cm^3, surface bathed in water 27,000 cm^2. Average cooling-water temperature about 30° C. Cooling water taken from ordinary water system. Cooling by closed circulation circuit. High-vacuum cock in preliminary pump oil immersed. Average current about 200 A. Surges up to about 400 A. The rise in pressure noted on this mutator under load, despite water cooling and mercury sealing, during four months, was only 7/1000 mm Hg (vacuum pumping being only resorted to three times a year and the plant running for 17 to 18 hours a day).

In the course of four months, the pressure should have been supposed to have increased by 70 mm Hg if the diffusion constant of $0 \cdot 277 \frac{cm^3 \cdot mm\ Hg}{cm^2 \cdot h}$ had been taken as basis, that is to say the pressure should have been about 10,000 times the figure measured. For this practical mutator case, the diffusion constant is only $1 \cdot 8 \cdot 10^{-5} \frac{cm^3 \cdot mm\ Hg}{cm^2 \cdot h}$ a figure which, as shown by the example just given, is not of any significance.

(2) *The permeability of steel tubes to hydrogen* with ordinary water taken from the ordinary supply system of a conductivity of about 2500 Ohms/cm at 20° C was measured. These are conditions met

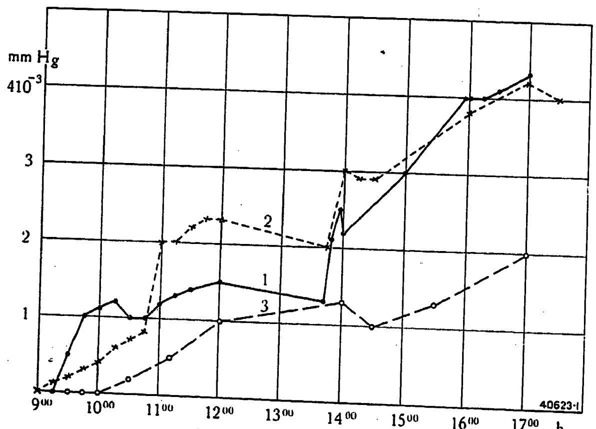


Fig. 126. — Diffusion of hydrogen through the wall of a seamless drawn steel pipe immersed in water from the ordinary supply system or in oil.

1. Test in H_2O at 60° C. 2. Test in H_2O at 60° C.
3. Test in Oil at 60° C.

with in practice. The steel tube is drawn and seamless of a wall thickness of 1·5 mm and a surface of 20 cm^2; it is bathed in still water, the temperature of which is 60° C. The preceding graphic representation shows the results of this experiment. Fig. 126 illustrates three series of tests, each lasting 8 hours, two being carried out with ordinary supply water and one with oil to ascertain the quality of the sealing of the apparatus. In eight hours, the actual pressure increase was $4 \cdot 15 \cdot 10^{-3} - 2 \cdot 10^{-3} = 2 \cdot 15 \cdot 10^{-3}$ mm Hg. It must be remembered that the hot-wire vacuum meter is air calibrated so that the real pressure rise for hydrogen is only about $1 \cdot 10^{-3}$ mm Hg. This results in a diffusion constant of $156 \cdot 10^{-3}$ cm^3 mm Hg/cm^2/h for a seamless drawn steel tube and a temperature of 60° C.

The following table gives the diffusion figures for several cases:—

Tests No.	Object of test	Duration of test Hours	Kind of cooling water used	Temperature of Water °C	Diffusion number $\frac{cm^3 \cdot mm\ Hg}{cm^2 \cdot h}$
1	Steel mutator of 7 mm wall thickness	2100	From the public supply system	abt. 30	$1 \cdot 8 \cdot 10^{-5}$
2	Seamless drawn steel tube, 1·5 mm wall thickness .	16	Ditto	60	$156 \cdot 10^{-5}$
3	Seamless drawn steel tube, 1·5 mm wall thickness .	14·5	Ditto	20	$26 \cdot 10^{-5}$
4	Seamless drawn steel tube, 1·5 mm wall thickness .	14	Distilled water	20	$30 \cdot 10^{-5}$
5	Seamless drawn steel tube, 1·5 mm wall thickness .	3	Ditto	90	$3100 \cdot 10^{-5}$
6	Seamless drawn steel tube, 5 mm wall thickness .	16·7	Ditto	95	$27{,}700 \cdot 10^{-5}$ Taken from scientific articles published.

It should also be noted, here, that the water from the public supply system used in tests 2 and 3 is rather less favourable as regards hydrogen-ion concentration than usual cooling water used with standard mutators. If the surfaces of the test tube immersed in water are covered by a rust proof coat of paint, as is customary with mutators and which our experience shows last for many years, the permeability to hydrogen of cases 2 and 3 which correspond to practical conditions, will fall still lower than the figures given. These are already negligible, so the new figures can be entirely disregarded. To summarize, it can be said that the very slight hydrogen ion diffusion through the water-cooled walls of steel rectifiers has, practically, no disadvantageous results, as is shown by our own observations on numerous

mutators and neither the danger of back firing nor the degree of vacuum are disadvantageously influenced, thereby.

Further, tests were carried out on the *continuous control of a discharge in mercury vapour, through the agency of a grid placed between anode and cathode.* This method of control forms the basic principal on which the Triode works in the technic of high-frequency and with which the flow of electrons, from the incandescent cathode giving them off, to the anode, is continually varied (controlled) by altering the grid voltage. Here the potential of the grid as compared to the cathode is always maintained negative. In a discharge in a gas, such as mercury vapour, it is generally impossible to attain continuous control by means of a grid. This is because when a grid is charged negatively during a discharge in a gas-filled chamber it surrounds itself — as is well known — with a sheath of positive ions which shields the negative field of the grid from outside influences. The sheath of positive ions is created through the electrons being repulsed by the negative grid so that a space free of electrons is produced in which there are only positively-charged ions. The grid has no effect outside of this ion sheath and, thus, cannot influence the discharge. In an electron discharge under high vacuum, this isolating ion sheath does not exist as there can be no positive ions in the high vacuum.

Under special testing conditions, it is, nevertheless, possible to regulate continuously a discharge in mercury vapour, with the help of a grid. This happens when the discharge of the anode is not an independent one, that is to say when it is one which is motived by the discharge initiating on the grid. If an arc is allowed to burn between the grid and the cathode, a part of the electrons moving towards the grid shoot through the holes in the grid and these can be taken up by the anodes situated behind. The anode current, that is the number of electrons shooting through the grid holes, is then about proportional to the grid current and this current is suppressed as soon as the grid current is cut out. Although the anode current can be considerably stronger than the grid current, when there are many holes in the grid, this discharge to the anode is, in no respect, an independent one. Further, it should be said here that only low currents can be controlled in this way, as, when the currents are stronger, the discharge becomes independent and in no relation to the grid current.

Fig. 127 shows diagrammatically the testing equipment used by us, and Fig. 128 the whole apparatus. This consists of a glass tube with mercury cathode 1, an anode 3 with a grid 2 placed in front of it, a main excitation anode 4, an auxiliary excitation anode 5 and an ignition anode 6. The tube

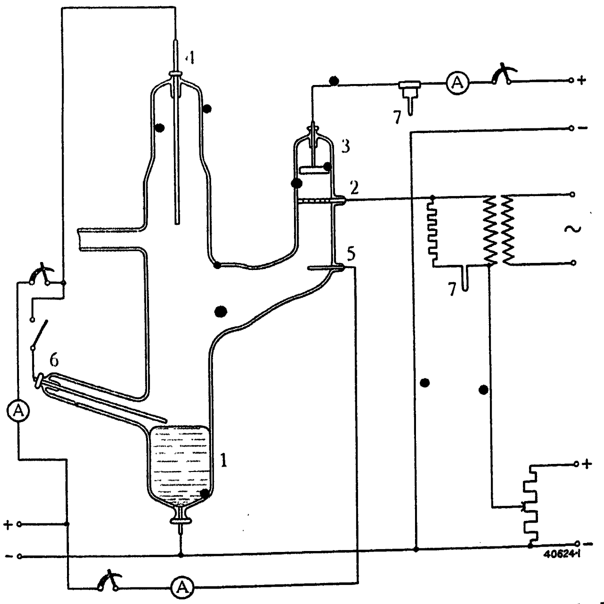


Fig. 127. — Diagrammatic layout of test on the continuous control of a discharge in mercury vapour, through the agency of a grid placed between anode and cathode.

1. Mercury cathode.
2. Control grid.
3. Test anode.
4. Main excitation anode.
5. Auxiliary excitation anode.
6. Ignition anode.
7. Oscillographic strip.

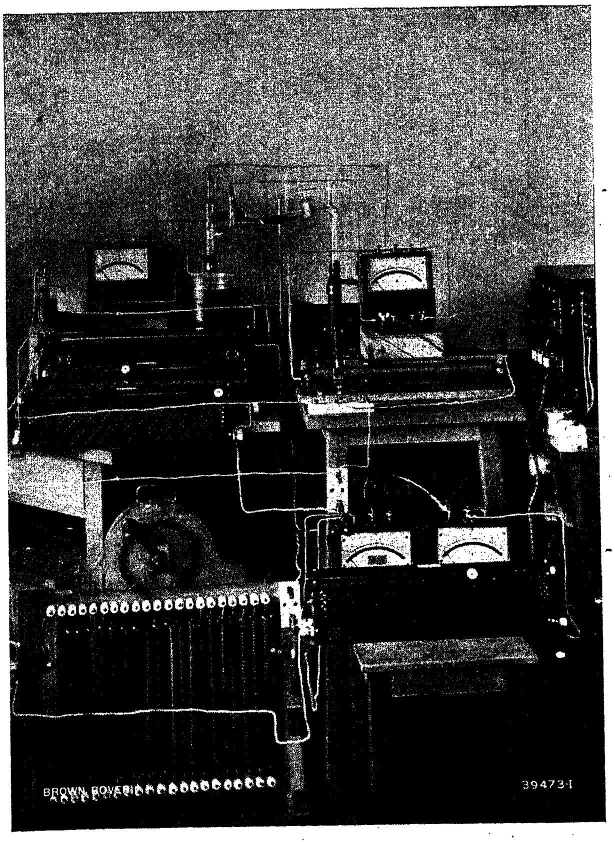


Fig. 127. — Layout of test on the continuous control of a discharge in mercury vapour, through the agency of a grid placed between anode and cathode.

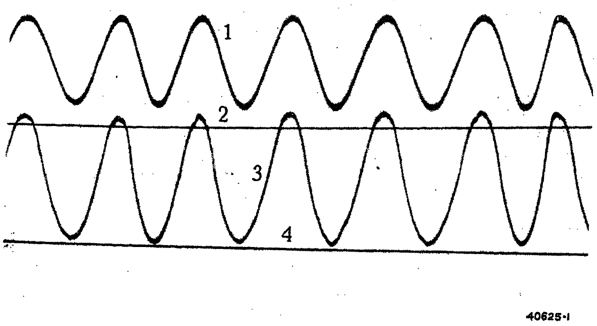


Fig. 129. — Continuous control of a discharge in mercury vapour, through the agency of a grid placed between anode and cathode.
1. Grid E. M. F.
2. Zero axis of grid E. M. F.
3. Anode current.
4. Zero axis of anode current.

was connected to a high-vacuum pump. The excitation arc to the excitation anode 4 kept up the cathode spot on the mercury cathode. The auxiliary excitation anode 5 was not absolutely necessary, it collaborates, however, to make the discharge stable. If, now, a positive D.C. voltage were impressed on the anode 3 and on the grid, and if an A.C. voltage were to be superimposed on the grid voltage, according to the diagrammatic illustration, the anode current would be modulated in time with this A.C. voltage. Fig. 129 shows an oscillogram obtained with this arrangement. As can be seen the anode current is composed of a D.C. current component corresponding to the D.C. current component of the grid voltage and of an A.C. component corresponding to the superimposed A.C. voltage of the grid. The highest anode current which could be constantly regulated was about 0·2 A, with the tube in question.

In the field of *testing of materials* we have to report on tests carried out on heat-proof *chromium-nickel steel*. These tests were motived by the discovery of fissures of various sizes below the upper rim of annealing pots, after the latter had been used for several months. These fissures were unevenly distributed round the circumference but always at the same height. The first conjecture, namely that these fissures were due to tensions could not be upheld after an exhaustive examination. The bending tests, analysis and microscopic tests showed that corrosion had been at work which had weakened the sheeting so much that, in some places, fissuring took place under the influence of heat expansion and contraction as well as of weight proper.

Test strips of sheeting were taken from the pot, being cut out in the sense of a generating line and were then bent round a diameter of about 60 mm (Fig. 130), so that the side corresponding to the inside of the pot became the side of the test-piece under tension. Already, after the piece had been bent through a small angle, a part of the strip showed considerable fissures which, on some cases, extended through the whole strip and this in places which seemed perfectly healthy before the bending test was initiated. This belt-shaped fissure zone runs round, about 10 cm from the upper rim, and is about 50 mm wide. The attack on the metal is only visible in the form of fissures on the inside of the pot, in a few places and, generally, the exterior reveals nothing. The whole zone, however, is covered by a heavy coating of oxidization and corrosion products. On the same test pieces but some centimeters above and below the fissure zone, quite sharp-angle bends could be carried out, the material showing no ill effect and no fissures.

An analysis of the sheeting was made to ascertain its quality and the corrosive coating of the fissure zone was scraped off and investigated.

Composition of sheet:—

C %	Si %	Cr %	Ni %
0·10	0·019	17·05	19·22

This analysis gives quite normal results corresponding to the alloy as specified.

Investigation of oxidized coating:—

It contains 0·319 % of sulphur besides the oxidization of the iron, the chromium and the nickel. Further SO_2 was unmistakably given off when the substance was brought to glow heat.

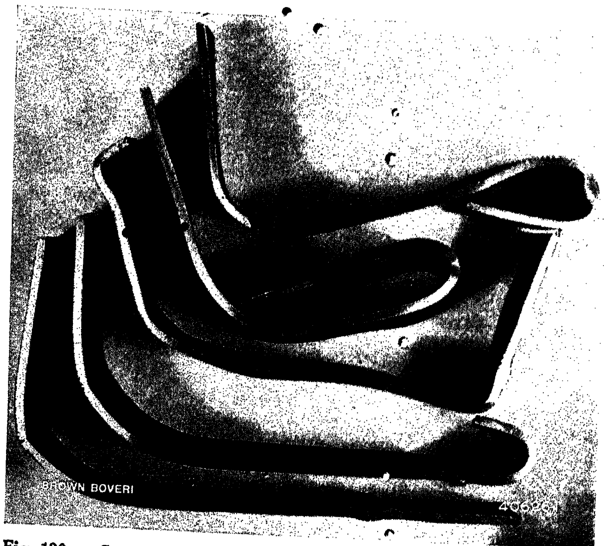


Fig. 130. — Strips of sheet metal for investigation of the resistance to heat of chromium-nickel steel.

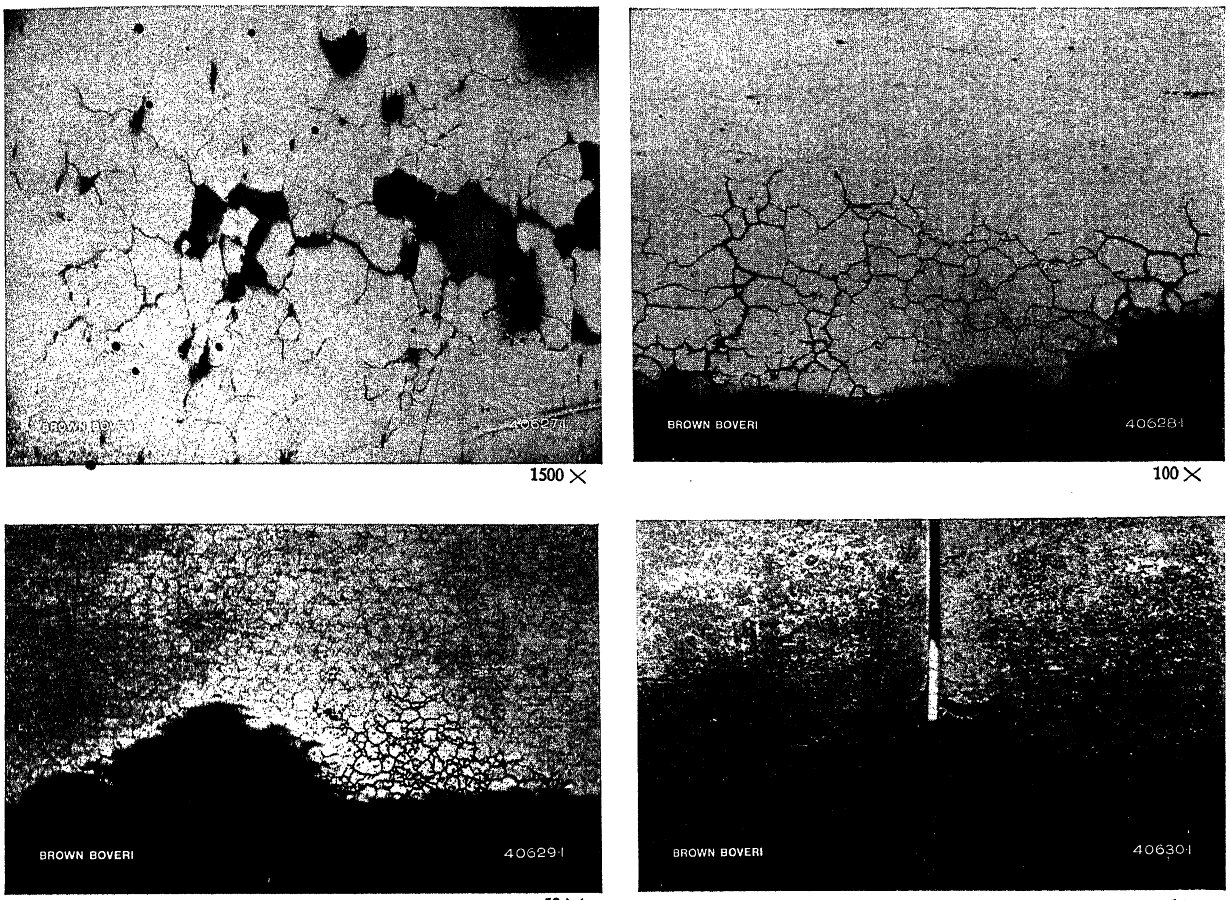


Fig. 131. — Microscopic photographs of heat-resisting chromium-nickel steel.

The fact that the sheet contains only 0·019 % of sulphur and that the corrosive substance contains 0·319 % of it gives an indication of the source of the trouble. As is known, nickel and austenite alloys containing nickel are particularly sensitive to the attacks of sulphur and its combinations. The sulphur penetrates rapidly between the grains and nickelous sulphide is formed which immediately leads to the disintegration and destruction of the metal.

The microscopic photographs, Fig. 131 confirm this conclusion. The photos show the typical crystal boundary attack characteristic of sulphuric corrosion as well as the disintegration of the crystals and their gradual destruction. The last photograph of the bending test shows clearly on the polished surface of the section the depth of the attack, in the fissure zone.

Interesting investigations were carried out to determine the cause of definite forms of fatigue ruptures. These cases of rupture were occurring significantly often in the shafts of lead hammers. Ten such shafts were investigated in all and the most varied results noted. The shafts are of malleable steel containing between 0·05 % C and 0·25 % C. The variations in strength are just as great. The ruptures generally take place at the section where there is a bend, but also, sometimes, higher up and, in rare cases, at the ring. The following ruptures could be classified roughly:—

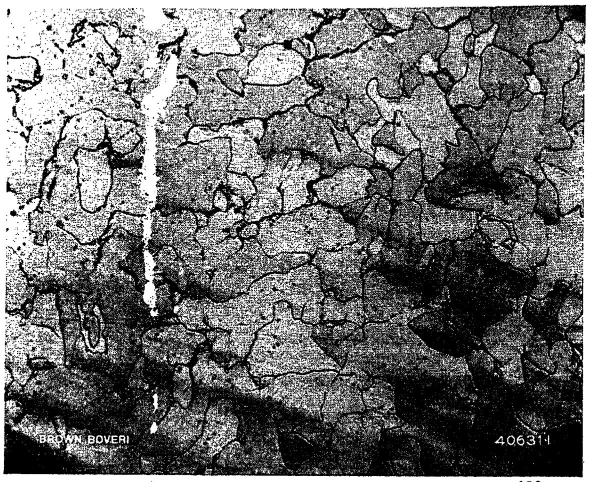
(1) The beginning of the break is a small fatigue rupture and then a final remaining rupture of usual grain size and shining surface.

(2) The rim is crystallized in very coarse grain size and the interior is of ordinary grain size.

(3) Uniform rupture of normal grain size, shiny, brittle without a fault which could be ascertained.

(4) Rupture starting from a notch due to a blow.

In all cases the shafts had been hardly treated as many marks of blows just under the hammer head testified to. If these shafts are then annealed, recrystalization takes place with very coarse grain at these places; the grain being nearly of a diameter of 2 mm, which leads to brittleness. When subjecting the metal to etching, stress lines were discern-



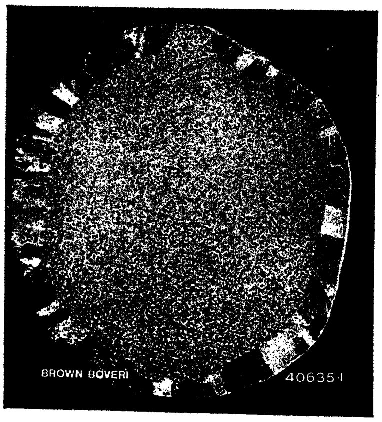
150 ×

100 ×

Fig. 132. — Microscopic photographs of the shafts of broken lead hammers (fatigue ruptures).

1500 ×

1500 ×



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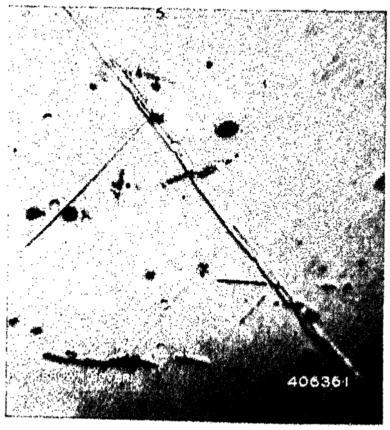

150 ×

able, in some cases, which lines occur, when soft steels have been tried beyond their elastic limit. The numerous slip bands in the crystals point to the same thing, these showing up under the microscope (Fig. 132). As workshop practise leads inevitably to too great stressing, a general deterioration of the pieces cannot be prevented. Periodic complete annealing puts off the moment of actual rupture; this annealing should take place at about 920 ^{0} C. We have reasons to suppose that such annealing processes are often carried out at lower temperatures which has rather a deleterious effect than the contrary, because it produces the recrystalization mentioned before and there is a transformation of the iron carbide, this first passing from Perlite to Cementite and, further, as time goes on, collecting on the crystal boundary as intercrystaline cementite, which again makes the metal very brittle.

Finally, impact tests were carried out on the hammer head end of the shafts and a Brinnel hardness test made simultaneously. The former results were very good and the hardness that of an ordinary steel.

To summarize, no common cause covering all the ruptures was found. In most cases a definite cause was determined but in the majority of cases no explanation is possible. Thus, it can be stated that the ruptures were due, in part, to over stressing and, in part, to ageing of the material. *(MS 880/S)*

K. Sachs (Parts I and III) P. Faber (Part II). (Mo.)

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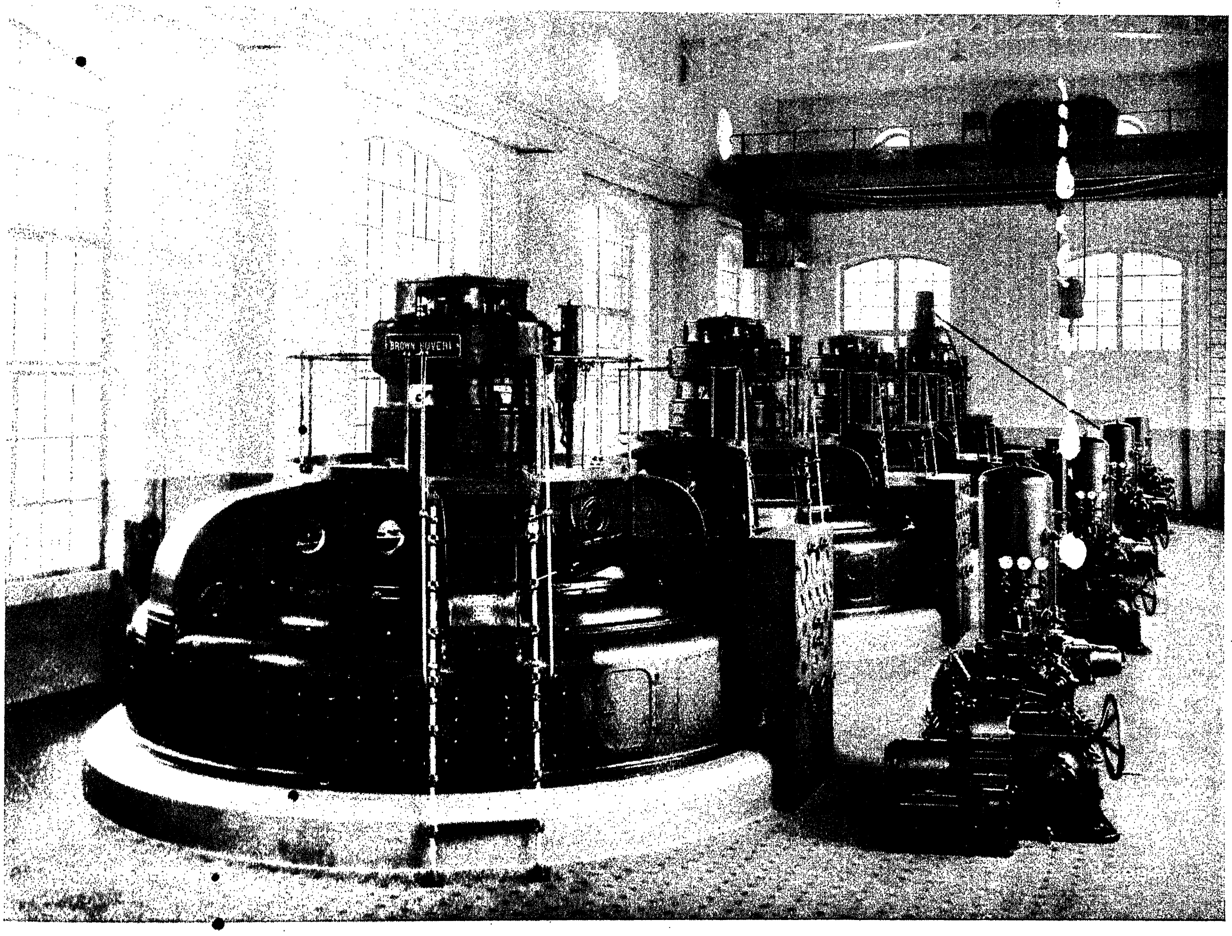
THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



HAGNECK POWER STATION OF THE BERNISCHE KRAFTWERKE A.-G., BERNE.
Four generators each of 3400 kVA, p. f. = 0·75, 16,000/17,600 V, 50 cycles, 187 r. p. m.

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Printed in Switzerland.

THE BROWN BOVERI REVIEW

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VOL. XXII MARCH, 1935 No. 3

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THE BROWN BOVERI WATER-JET HIGH-VOLTAGE ELECTRIC BOILER.

Decimal index 621. 181. 646.

I. GENERAL.

A short time ago, Brown, Boveri & Co. placed on the market a new type of electric boiler which differs completely from all previous designs both in its construction and the principle on which it works.

Already during the war and in the succeeding years Brown Boveri were interested in the construction of electric boilers, studied all developments in this field, and acquired a large amount of practical experience.

The new design of boiler is based on practical experience, a fact which has enabled certain disadvantages of a thermal, electrical and mechanical nature—common to the usual types of electric boilers—to be avoided. At the same time, the main object aimed at was to meet the requirements of modern industry.

The principal feature of the Brown Boveri boiler is that the electric current does not, as in standard types of boiler, flow from immersed electrodes through a stationary column of water, but is conducted through water jets which, as will be described later, radiate continuously from nozzles to the electrodes.

The construction and mode of operation of the Brown Boveri boiler is shown in Fig. 1.

A Brown Boveri electric boiler plant comprises essentially the boiler proper a with the built-in electrodes b, the ejection pipe c, a circulating pump with driving motor d, the usual boiler fittings and the requisite switchgear.

The three electrodes are arranged concentrically about the vertical ejection pipe, which is provided with three vertical double rows of nozzles. The circulating pump delivers water from the lower part of the boiler into this tube, from which it flows in jets against the electrodes. These are so constructed that the water impinges on their inner surface tangentially, spreads over the inner surface and is so deflected that it acquires a circulative and downwards motion. In this way, dispersion of the water, which would interfere with the electrical conductivity, is prevented. At the same time the centrifugal effect assists the separation of the steam produced from the water. At their lower ends the spiral shape of the electrodes changes into a circular one, so that a tubular extension is formed which collects the water caught in the spirals and concentrates it into a jet. A sheet-metal cross is built into this tubular extension to stop the circulative motion so that the water leaves the electrode at the bottom in a compact downward jet. The water then impinges on a perforated plate, which is electrically connected with the side of the boiler, and flows through it into the collecting chamber.

In this manner two current paths of constant length are formed per phase between the neutral point of the electrical system, to which the boiler shell and the injection tube are connected, and the electrodes, one of the paths being between the ejection tube and the electrodes, the other between the electrodes and the afore-mentioned perforated plate. Along both these paths the water is heated and evaporated due to its own resistance. Under normal

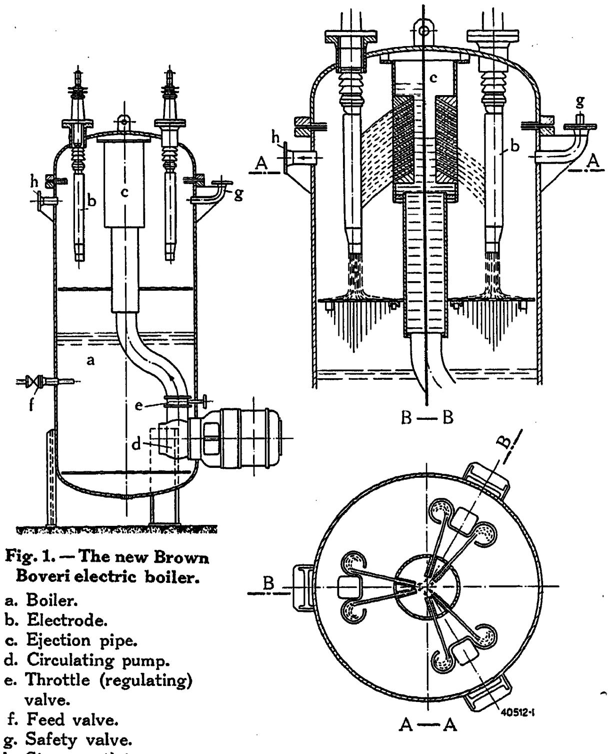

Fig. 1. — The new Brown Boveri electric boiler.
a. Boiler.
b. Electrode.
c. Ejection pipe.
d. Circulating pump.
e. Throttle (regulating) valve.
f. Feed valve.
g. Safety valve.
h. Steam outlet.

operating conditions the jet water is practically at evaporation temperature, as it flows continually in a closed circuit, so that a very small portion of the electrical energy supplied is used for heating the water, the major portion being used for evaporating it.

Apart from the bushing insulators, the Brown Boveri electric boiler has no ceramic parts inside it. Furthermore, the insulators are not immersed in the water. This is a very important advantage, as it is well known that ceramic parts which are immersed in boiler water are subject to attack and have to be replaced from time to time.

The output of the boiler is regulated exclusively by varying the quantity of circulating water, so that, according to the output, a greater or smaller number of nozzles are in use. Under maximum load, therefore, water sprays on to the electrodes over their whole length and under partial load over part of their length, only. The adjustment of the quantity of water is effected by the throttle valve e.

The Brown Boveri high-voltage boiler is normally built for operation with three-phase current of 2000 V upwards, and for outputs of 300 kW to 10,000 kW and above. The boiler can, however, also be designed for single-phase and two-phase alternating current. It can be built to suit all steam conditions met with in practice.

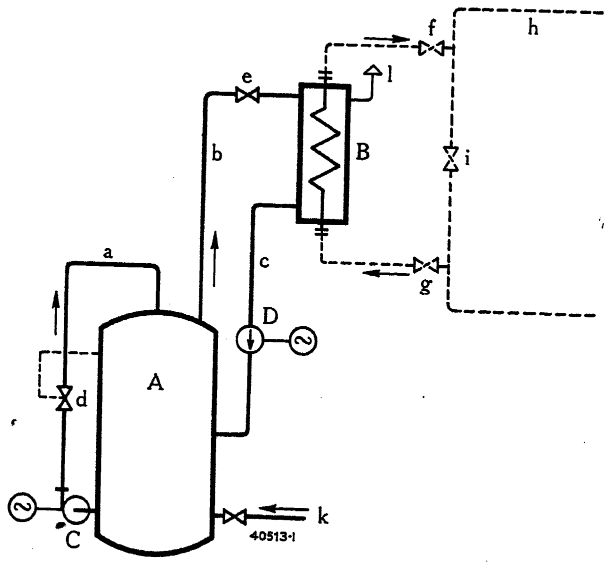

Fig. 2. — Electric boiler plant for producing hot water.

A. Steam boiler.
B. Heat interchanger.
C. Circulating pump.
D. Auxiliary pump.
a. Circulating water pipe.
b. Steam main.
c. Return pipe for the condensate.
d. Regulating valve with automatic pressure regulation.
e. Steam valve.
f, g, i. Valves.
h. Heating main.
k. Feed pipe.
l. Air blow-off valve.

When it is to be used as a hot-water boiler for supplying baths, heating installations, etc., the arrangement shown in Fig. 2 is recommended. The steam produced in the boiler A gives up its heat in the separately mounted heat interchanger to the water to be used for heating and flows back to the boiler as condensate.

A great advantage of this arrangement is that the water which flows on to the electrodes and serves as a heating resistance is insulated in a closed system. The operation of the electrode equipment is, therefore, independent of the degree of purity and condition of the water used for the actual heating.

The two circuits are thus totally independent of each other, so that the heating water does not come into contact with parts which have an electrical potential above earth.

The Brown Boveri electric boiler can, however, also be designed for the direct production of hot water. This latter design is chiefly used for central heating plants.

II. REGULATING GEAR.

The standard boiler with hand regulation has the following accessories:—

A steam stop valve, two safety valves, a non-return valve, a feed valve, a sludge valve, a manometer, a water-level indicator and a throttle valve in the water circulation pipe for regulating the output.

The boiler can be equipped with various regulating systems:—

(1) *Hand regulation.*

Hand regulation is confined to adjusting the output or keeping constant the steam pressure by operating the throttle valve, and to supplying make-up water by operating the feed valve, according to the water level.

(2) *Automatic regulation.*

(a) For keeping the pressure or the temperature at a definitive value. When the output varies, a pressure regulator (or temperature regulator) is built in, which operates the above-mentioned throttle valve by means of electrical equipment. It is also possible with an automatically controlled boiler to vary the load between practically 0 and 100% of the rated output continually and without trouble. The mode of operation of the automatic pressure regulator can be seen from Fig. 3.

The pressure regulator 4 operates an electrical change-over contact 6 and closes the circuit to the

control motor 9, thus altering the opening of the throttle valve 3. The movement of the throttle valve operates back on the regulator through a system of levers and serves as a recall mechanism, thus ensuring that the operation is free from hunting. The desired pressure is set by the handwheel 15 and can be adjusted between wide limits.

The change-over switch 13 enables either "automatic" or "non-automatic" operation to be used. With non-automatic control the output of the boiler is adjusted as desired to a given value by the switch 12.

In certain cases, and particularly when the output is small, it is advisable to use automatic thermostat control instead of the pressure regulator. The

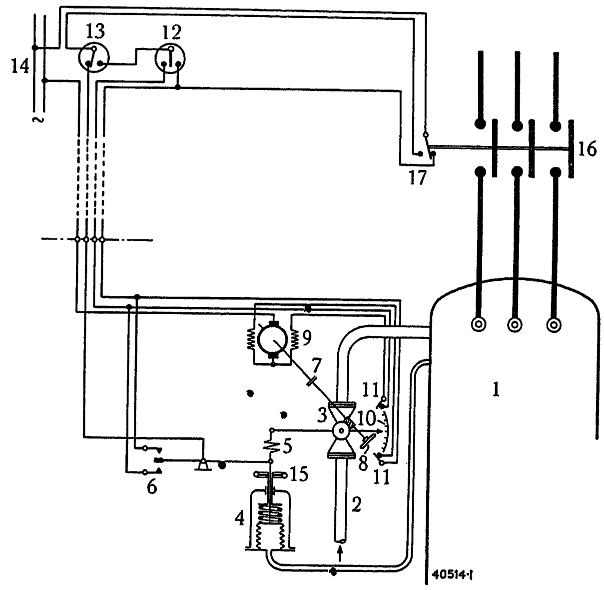

Fig. 3. — Diagrammatic arrangement of the automatic pressure regulation.

1. Boiler.
2. Circulating water pipe.
3. Regulating valve.
4. Pressure regulator.
5. Recall spring.
6. Switching contacts.
7. Friction coupling.
8. Handwheel.
9. Regulator motor.
10. Scale.
11. Limit contacts.
12. Change-over switch for hand regulation.
13. Change-over switch for "automatic" or "non-automatic" regulation.
14. Auxiliary current supply.
15. Handwheel for adjusting the pressure.
16. Oil circuit breaker.
17. Auxiliary contact.

control motor 9 can then be dispensed with and the throttle valve hydraulically operated.

(b) For keeping the water level constant, the automatic regulating equipment shown in Fig. 4 is used.

This works on a purely mechanical principle:— a diaphragm E, which is influenced by the prevailing water level in the boiler, controls the feed water valve proper F. This valve is operated by water under pressure, the feed water supplied by the feed pump being itself used for this purpose.

In certain cases, special systems of regulation can be adopted. For example, the power consumption can be remote-controlled from a power station or by means of time switches. It is also possible to design the power-regulating gear so that a given load on the network is kept constant by automatically adjusting the power consumption of the boiler.

By means of the regulating systems described, it is possible to avoid any moving parts, except the throttle valve, inside the boiler. Thus no packing glands are necessary and no special servo-motors, which often have an unfavourable effect on the satisfactory operation of a plant.

III. THE ELECTRICAL GEAR.

The electrical equipment for connecting the boiler to the network is mounted, as usual, in a switch panel situated in the immediate vicinity of the boiler. Fig. 5

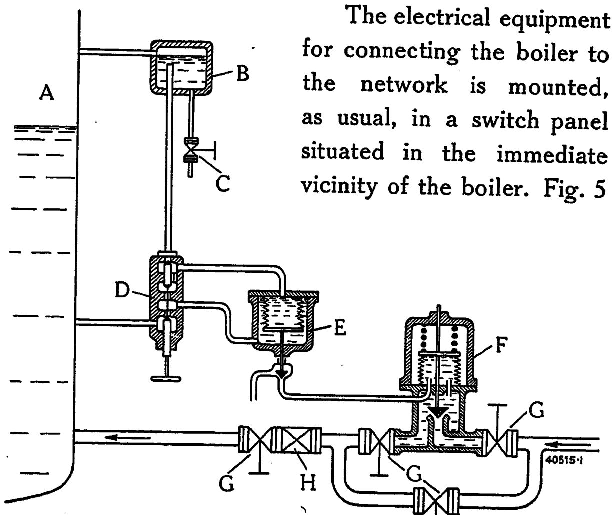

Fig. 4. — Automatic feed water regulation.

A. Boiler.
B. Condensing chamber.
C. Sludge valve.
D. Double lift stop valve.
E. Feed water regulator.
F. Feed water regulating valve.
G. Stop valve.
H. Non-return valve.

shows the fundamental diagram of connections of the electrical gear for such a plant.

The electric boiler is coupled up to or disconnected from the network by the oil circuit breaker 2,' which is fitted with over-current relays in all three phases and with no-volt release.

For the electrical measurements, the standard measuring instruments 8 to 12 are provided, enabling the operation of the boiler to be checked from the switch panel. The change-over from automatic to non-automatic operation, or vice versa, is also effected from here, as well as the regulation of the power during non-automatic working. The main breaker is

also provided with auxiliary contacts which cause the regulating throttle valve to be closed by the electric motor when the breaker opens automatically.

When the boiler is cut out automatically, the operator's attention is drawn to the fact by an alarm

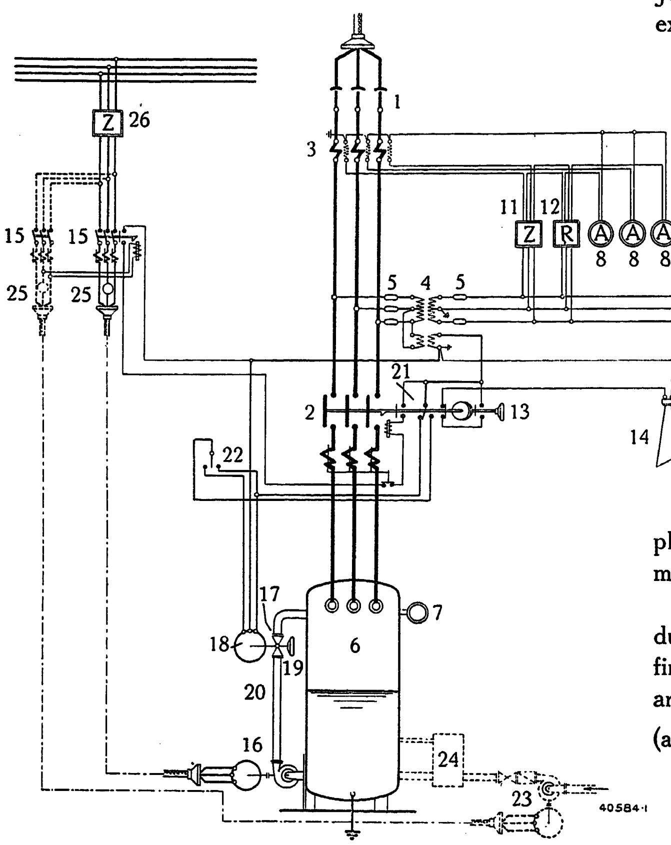

Fig. 5. — Diagram of connections of a high-voltage electric boiler plant.

1. Isolating switch.
2. Oil circuit breaker with over-current and no-volt release.
3. Current transformer.
4. Voltage transformer.
5. Fuses.
6. Electric boiler.
7. Manometer.
8. Ammeter.
9. Voltmeter.
10. Change-over switch for voltmeter.
11. Meter for the boiler.
12. Recording wattmeter.
13. Hand drive.
14. Horn.
15. Switchbox.
16. Circulating pump set.
17. Regulating valve.
18. Motor for remote control.
19. Handwheel.
20. Circulating pipe.
21. Auxiliary contacts.
22. Change-over switch for remote control by hand.
23. Feed pump with motor.
24. Feed-water regulator.
25. Amperemeter for auxiliary set.
26. Meter for auxiliary set.

horn. The horn is silenced by drawing back the hand drive of the oil circuit breaker into the "Out" position.

The minimum voltage coil of the breaker, the horn and the regulating motor of the regulating valve are connected up to a special voltage transformer. The two latter circuits can be fed from the auxiliary service source of current.

The operations to be made when starting up the boiler are regulated by interlocks between the main breaker and auxiliary switches.

IV. COMPARISON OF THE RUNNING COSTS OF COAL AND OIL-FIRED BOILERS AND THE NEW ELECTRIC BOILER.

The following data allows of calculating the production of heat and steam in an electric boiler:— Joule's Law states that the following relationship exists between electrical and thermal energy:

$$1 \text{ kWh} = 860 \text{ kilogramme-calories.}$$

From this it follows that the weight of steam (saturated steam) shown in Fig. 6 can be produced theoretically per kWh.

The efficiency of the electric boiler varies between 96 and 99%, according to the size. The losses are constituted by the heat in the sludge removed, by heat radiated from the boiler and by the small proportion of the electrical energy used for driving the circulating pump set. By far the greater proportion of the last named is also utilized in the form of heat. For the sake of completeness, the loss due to electrolysis should also be mentioned, but this is so small as to be negligible.

In order to judge of the efficiency of steam production by electricity as compared with coal or oil-fired boilers, the production costs, using both methods, are set out below.

(a) *Coal or oil firing.*

$$\text{Cost per kg of steam} = \frac{\text{price of coal (or oil) per kg}}{\text{evaporation coefficient.}}$$

The evaporation coefficient is understood to be the weight of steam in kg produced per kg of fuel, the following equation being used:

$$X = \frac{H \cdot \eta}{i - t_s} \quad \text{where } H = \text{calorific value of fuel}$$

η = efficiency of boiler

$i - t_s$ = heat content of the steam less heat content of the feed water.

(b) *Electric heating.*

$$\text{Cost per kg of steam} = \frac{\text{price of current per kWh}}{\text{kg of steam per kWh.}}$$

If, now, the cost per kilogram of steam is to be the same with the electric boiler as with the coal or oil-fired boiler, then the cost of electric power must be per

$$\text{kWh} = \frac{\text{price of coal (or oil) per kg} \times \text{kg steam per kWh}}{\text{evaporation coefficient}}$$

as represented in Fig. 7.

V. ADVANTAGES OF THE NEW ELECTRIC BOILER.

In considering the question of purchasing an electric boiler of the new type, the above-mentioned facts must not alone be taken into consideration.

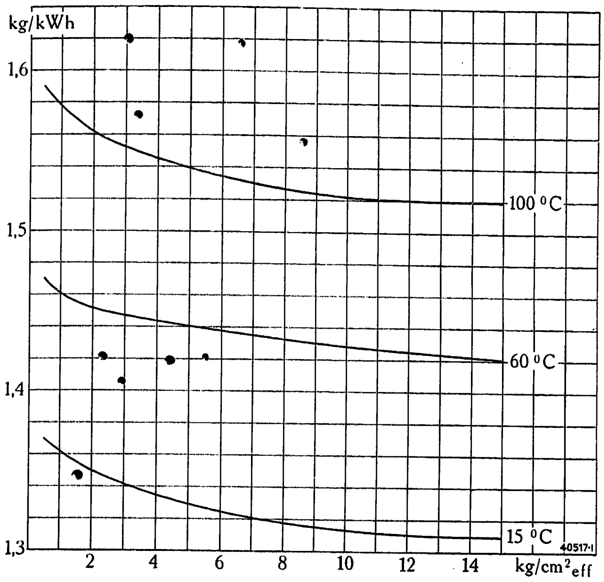

Fig. 6. — Weight of steam, as a function of the pressure, which can be theoretically produced with various feed-water temperatures.

Above all, the following advantages possessed by this boiler must be considered:—

(a) The operation of the boiler is extremely reliable, as no higher temperatures occur anywhere in the boiler than the temperature of evaporation corresponding to the working pressure. There is also no danger due to an exceptionally low water level or to the complete failure of the feed water supply. A stand-by feed pump, necessary with other types of boilers, is not, therefore, required.

(b) Steam can be raised very quickly, as starting up is confined to switching on the current, and the full pressure is rapidly attained.

(c) The output can be regulated very quickly and thus readily adapted to changing operating conditions.

(d) Little attention is required, as no fuel has to be conveyed to the boiler and there are no ashes to be removed. The operation can even be made full automatic without much extra cost.

(e) The boiler and its auxiliaries take up little space.

(f) The operation is very clean, and no soot, smoke or dust is produced.

(g) Long steam pipe lines are avoided due to the possibility of erecting the boiler at the point where the steam is required.

(h) There is no wattless-current consumption, and therefore, the loading of the network is very favourable.

In view of the advantages enumerated above it is frequently possible to operate electric boilers economically even when the cost of current is comparatively unfavourable.

Certain electric boilers place specific requirements on the properties of the water used, which functions as an electrical resistance and must, therefore, be conductive. Now the properties of water differ to a great extent and, in addition, the conductivity varies greatly during operation, this necessitating special measures to ensure stable conditions.

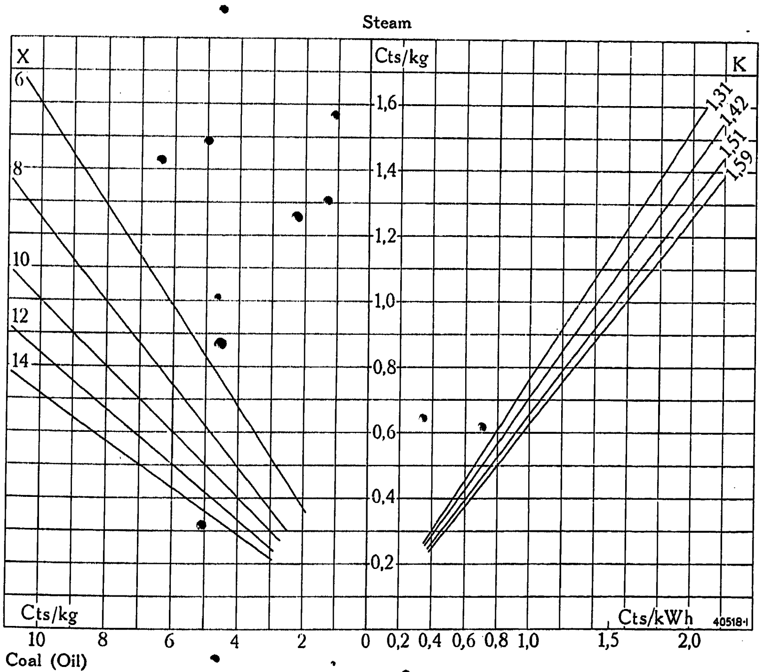

Fig. 7. — Cost of steam as a function of the price of fuel for various evaporation coefficients, and as a function of the price per kWh for various quantities of steam produced per kWh.

X = Evaporation coefficient. K = Weight of steam produced in kg per kWh.

The preceding remarks show that the lowest allowable resistance of the water, prescribed by the boiler manufacturer, plays an important part in the choice of a boiler system and it is obvious that, frequently, that system of boiler will be chosen which allows the lowest specific resistance figure.

This is the case with the new Brown Boveri electric boiler as it is precisely, the Brown Boveri system which allows of the highest specific loading of the electrodes.

The characteristics and the operating method of Brown Boveri boilers further offer the greatest guarantee of an even load on the three phases of the system and of entirely smooth regulation of the output.

VI. GENERAL CONSIDERATION AND FIELD OF APPLICATION.

As a rule, the production of steam or hot water in an electric boiler enters

into consideration where it is desired to utilize surplus — and therefore cheap — electrical energy from hydro-electric power stations. For this purpose, waste current, which is available at off-peak periods, e. g., during the night or over midday, comes first and foremost into consideration. By connecting up an electric boiler, it is often possible to prevent large quantities of water flowing off unused, at any rate in such plants as are not provided with pumped storage, or such where the possible storage cannot be fully utilized in view of certain water regulations in a given catchment area of a river.

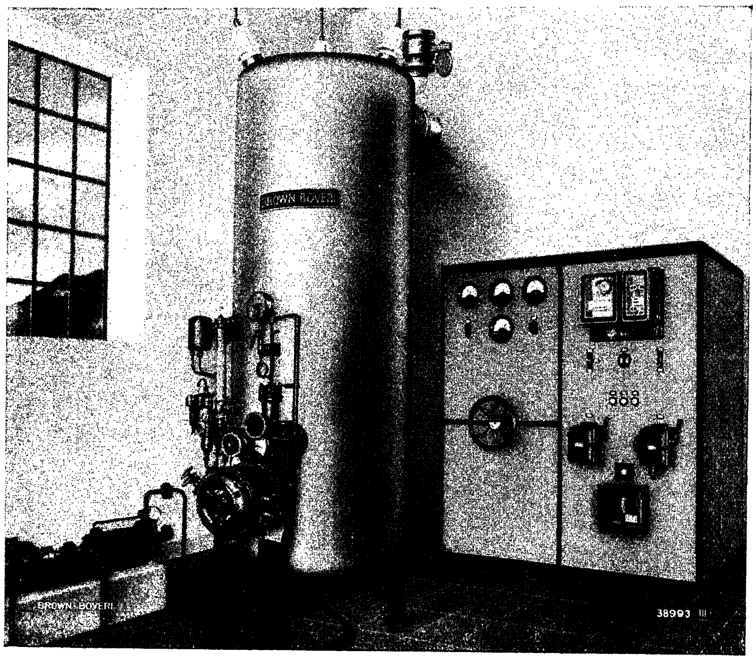

Fig. 8. — View of a Brown Boveri electric boiler plant.

The electric boiler has been most widely adopted in countries where there is a large amount of water power, because the above mentioned surplus or waste current can be sold at prices which enable the heat produced by electricity to compete with that raised in fuel-fired boilers. The electric boiler has, however, also been used in networks fed from thermal power stations, though such cases are exceptional as the multiple conversion of the power — which is accompanied by heavy losses — can only be of interest, very rarely.

A somewhat more favourable case is encountered in combined heating and power plants or in industrial plants where the exhaust steam from the turbines is 100 % utilized for heating purposes, no condensation then being used. If, in such plants, the electric power produced and corresponding to the full steam load, is not all required, it is possible that the supply of electrical energy to an electric boiler might be advantageous. Since the exhaust steam can be used in the main station, the average total heat consumption is no more than 1200 kcal/kWh, as compared with about 4000 kcal/kWh encountered in a typical modern power station without waste heat utilization.

A further field of application for electric boilers which might be mentioned is in thermal stand-by power stations, where they can be used for keeping the large steam boilers warm, i. e., always ready for operation, so that in an emergency the power station can supply electric power in the shortest possible time. It is well known that, in order to keep a boiler warm, a large amount of energy must be expended which is never recuperated. This duty can be immediately fulfilled by the electric boiler, if the waste energy from hydro-electric power stations connected to the same network as the thermal power station is used for raising steam which is employed for keeping the large boiler plant warm.

For completeness, attention is drawn to those plants which utilize waste fuel, for example, power stations which are driven by natural gas or blast furnace gas. The first mentioned should, in particular, be in a position to supply electrical energy at an especially favourable price, for the production of heat electrically.

The new electric boilers can also be connected in parallel or in series with existing coal or oil-fired boilers. When such a combination is used, it is most advantageous to arrange that the current consumed by the electric boiler be adapted to the load diagram desired by the supplier of the current, while the fuel-fired boiler covers the difference in the requirements. The fuel-fired boiler can also be used for heating the feed water of the electric boiler, or if the fires are drawn and the insulation is good, and also if it is possible to shut off the flues completely, it can be used as a heat accumulator.

The employment of these new electric boilers is of particular interest to the following industries:—

Chemical industries, cellulose and paper making factories, the textile industry, breweries, tobacco factories, chocolate works, factories associated with the milk and food stuffs industries, cheese factories, large agricultural undertakings, etc., also hot water plants for central heating installations, bathing and washing establishments, as well as swimming baths, etc.

(MS 864) *E. Soldati. (E.J.B.)*

THE UNTERWASSER-ILTIOS FUNICULAR RAILWAY EQUIPPED WITH REMOTE CONTROL FROM THE CAR.

Decimal index 625. 52 (494).

THE funicular railway, connecting the Upper Toggenburg locality of Unterwasser to the Iltios Alp, opens up the Churfirsten region to tourist traffic and makes more accessible a part of Eastern Switzerland which has long been popular as a centre of walks and climbs in summer and of ski-ing tours in winter. It also facilitates economic connections between the lower valleys and a, hitherto, rather inaccessible alpine region and is, therefore, of some local importance.

The construction of the railway was begun in the autumn of 1933, according to the plans of Mr. A. Weidmann, engineer of Küsnacht near Zürich; it was concluded by the end of July, 1934, and service initiated after very satisfactory trial tests. Brown Boveri delivered the drive of the haulage engine, designed for remote control from the car as well as for hand control by an operator in the machine station. The complete mechanical equipment of both the railway itself and the framework of the cars was delivered by the L. von Roll'sche Iron Works, Berne.

Fig. 1. — General view of the Unterwasser-Iltios funicular railway.

This funicular railway is especially interesting on account of the automatic regulation of the speed of the cars at entering the stations, a system which was successfully used on the Davos-Parsenn Railway and which has been improved upon in the present case. It eliminates the flywheel which was in general use, before, as a weight compensator for the variations in the loading of the cars, but, nevertheless, makes it possible to bring the cars to a stop on, practically, the same spot in the termini, independently of their respective loadings.

The actual length of the railway is 1210·5 m with gradients varying between 20·9 and 45·7%. The difference of altitude of the two termini is 431·2 m. The gauge is 0·80 m and the radius of the sharpest curve is 200 m. There are two cars each of 4800 kg dead weight, built to carry 44 passengers. The speed is 3·2 m/sec and the total travelling time for one trip is about 6 1/2 minutes. The hourly carrying capacity of the railway is 330 passengers in either direction. The driving station is supplied with power from a three-phase overhead transmission line through a high-voltage cable which forms its continuation. The power comes from the St. Gallisch-Appenzellische Kraftwerke under the form of three-phase current 10,000 V, 50 cycles. This voltage is stepped down to 380/220 V in a transformer station placed in the upper terminus.

The drive of the winding gear is lodged in the upper station. The big driving wheel, over which the cable runs, is, itself, driven through an oil-immersed reduction gear, by a six-pole three-phase induction motor of 80 kW rated output. Two brake discs, one for the electro-magnetic or alternatively hand-operated brake and the other for the emergency brake, as well as a mechanical centrifugal governor, to prevent excess speeds, are all mounted on the motor-driven shaft of the reduction gear. According to whether the funicular is operating under remote control or under the supervision of a machinist, the control of the electro-magnetic or hand-operated brake is through the agency of a brake-lifting magnet or through the usual mechanical hand control. The braking gears are connected up to the respective drives by a simple coupling device. The emergency brake is lifted by hand mechanism and is automatically applied through the play of rod connections. The emergency brake comes into action when the travelling speed exceeds

the rated figure by more than 25 %, through the agency of the centrifugal governor, mentioned before. It also acts when the reduced speed set to for entering the termini is exceeded and, finally, it acts when a car runs over the proper stop position in the station.

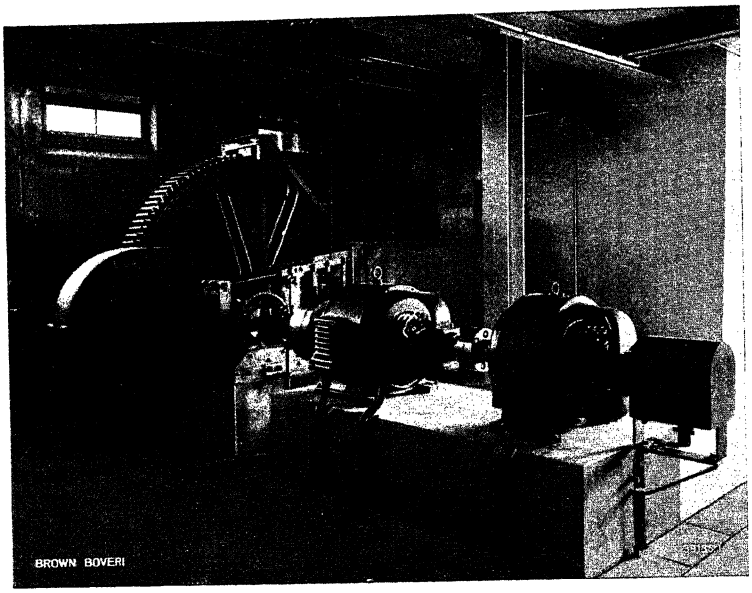

Fig. 2. — Machine room with the winding gear for the funicular railway. Haulage motor and D. C. braking machine with built-on centrifugal switch.

This brake, however, can also be applied from the machinist's post, by hand, at any moment. When remote control of the funicular is being used, the application of the emergency brake brings about the tripping of the oil circuit breaker, through the agency of a contact device; this leads to the electro-magnetic brake acting as well, and this double braking might result in the slowing down of the cars too sharply. A special mechanical compensating device prevents this occurring.

On economic grounds, namely, in order to operate the line with a small staff, the funicular is usually run with remote control from the car. The machine plant has no operator, under these conditions, and the railway is run by the car attendant alone. The conductor on the car going down can start the cars by means of a contact rod, secured to the front wall of the car, which is brought into contact with the control wire running alongside the railway line. Starting, running and stopping of the cars in the termini are absolutely automatic, once this starting operation has been carried out. Brown Boveri have developed and applied, here, for the first time, a new type of control to allow of the automatic regulation of the run and especially of the slowing down to a stop in the stations, at practically the same point, which is especially difficult when dealing with funicular railways handling heavy loads and operating at high speeds. Observations on the working of this control during the trial tests and under subsequent service conditions have shown that it meets every requirement for safe and economic service.

The correct stopping of the cars in the termini presents difficulties when automatic service is used, as the loading of the cars may vary very much, which means that the braking distance travelled over differs correspondingly when the standard braking devices in use up till now are used (one or two shoe brakes actuated by an electro-magnet or a brake lifting motor). This is because the braking effect cannot be adapted to every load. By using a flywheel as mass compensator for load fluctuations it is possible to circumvent this difficulty to a certain extent. In small plants, this simple solution may still be considered practicable, but it cannot be recommended for bigger railways, as it means using a very big flywheel in order to bring the cars to a standstill within a range of 1—2 m. A bigger distance range than this means longer platforms in the stations and, therefore, heavier building costs. On the other hand, a heavy flywheel consumes correspondingly more power to accelerate the additional masses, that is to say calls for a more powerful driving motor and, especially, stronger

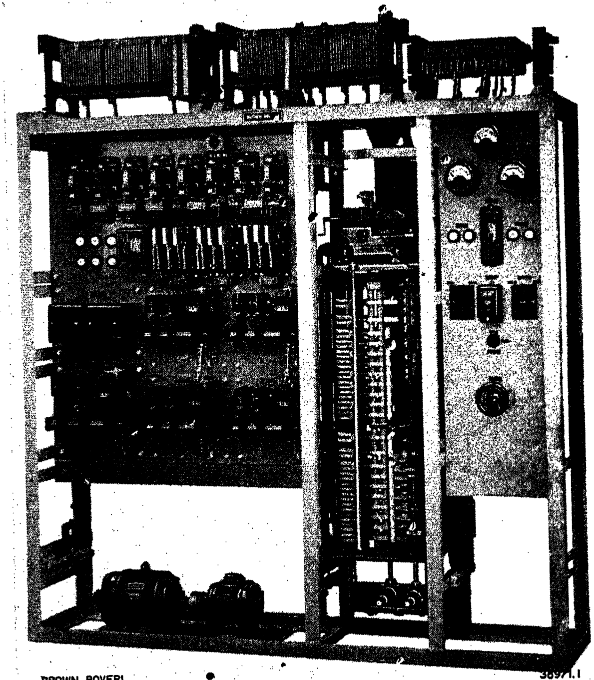

Fig. 3. — Switchgear frame holding the automatic control gear of the plant.

braking devices. The greater demand put on the mechanical brakes means more wear of brake linings and frequent replacement of same. Further, as a rule, the braking effect is rather sudden, as too long a braking distance is inadmissible if heating up of the mechanical brakes is to be prevented. All these difficulties are avoided by using a braking machine according to the newly developed Brown Boveri system of control. A D. C. generator is direct-coupled to the haulage motor, and this generator takes over the braking down of the cars to that reduced speed with which they enter the stations at the end of the run, after which they are stopped by an electro-magnetic brake and always on, practically, the same spot. The cars are thus brought to a stop in two time stages, the first of which can be chosen as long as desired making for soft and smooth braking down to the station entry speed. The braking power freed by the first braking action is converted by the D. C. machine into electrical energy and consumed in a cast iron resistance. Both, the haulage motor and the braking machine are regulated in connection with the set of resistances belonging thereto by a cam-type controller driven by a servo-motor. By proper choice of the characteristic of the D. C. machine, suitable graduation of the braking resistance and adjustment of the switching speed of the controller, it is possible to attain automatic adjustment of braking action to the various car loadings on a wide range, so that the speed of the cars is brought down from the travelling speed to the reduced speed for entering the termini under fairly constant and not excessive brake retardation. There is no special difficulty in braking down from this low speed to a stop by means of an electro-magnetic brake. It is obvious that, in this latter case, there will be no great difference between the positions in which the cars stop, whatever the difference in their load may be.

The greatest distance between the stopping points of the cars in the stations, corresponding to the maximum variations in the loading of the cars, was only about 1 m, this with a speed of entry into the stations of 1·0—1·35 m/sec and a braking distance of 0·75—1·75 m. The stressing of the electro-magnetic brake is, thus, reduced to a minimum and the brake hardly heats up at all. The wear, in service, must, consequently, be very slight indeed.

According to service conditions, the haulage motor may also be utilized to regulate the entry into the station. This occurs when the car on the up-gradient is heavily loaded as compared to the other. The haulage motor then functions to reduce the effect of the braking effort developed by the dynamo machine and the simultaneous braking effect of the difference in the loads of the cars. In this case, the haulage motor has a sufficiently big rotor resistance inserted in order to reduce its torque. The braking machine which, for reasons of safety, is always connected up during the first braking period, now plays a very slight part in the braking operation.

There are electro-magnetically operated switching contactors for the switching in and out of the motor and the braking machine, as well as for the electro-magnetic brake and the rest of the auxiliary devices. Relays are employed for the automatic regulation of the service. The final stopping of the car is brought about by an end-travel change-over switch in the upper station which is actuated by a trip piece on the car itself, while the first braking period is initiated by a contact device on the car-position indicator. The connections of the automatic control of the railway are so designed that, if an apparatus breaks down, the plant is brought to a stop by the electro-magnetic brake.

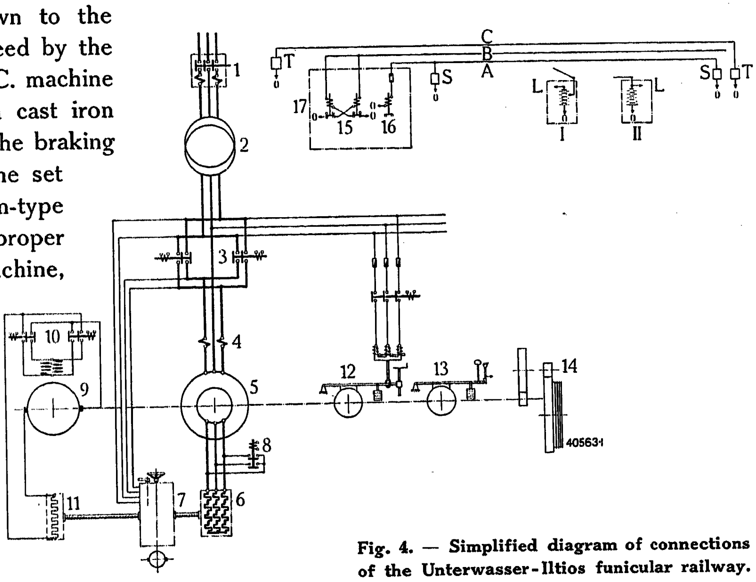

Fig. 4. — Simplified diagram of connections of the Unterwasser-Iltios funicular railway.

1. Oil circuit breaker.
2. Transformer.
3. Reversing contactor of stator.
4. Over-current relay.
5. Haulage motor.
6. Starting resistance.
7. Starting and braking controller with servo-motor and hand drive.
8. Contactor for short-circuiting rotor.
9. Braking machine.
10. Braking contactor.
11. Braking resistance.
12. Service brake for electro-magnetic and hand operation.
13. Emergency brake.
14. Winding gear.
15. Control relay.
16. Emergency relay.
17. Automatic control gear.

I. Funicular car (24 V control voltage).
II. Funicular car (36 V control voltage).
A. Signal and emergency-stop wire.
B. Control wire.
C. Telephone wire.
L. Light.
S. Signal bell.
T. Telephone.

The control gear also includes the requisite protective and supervisory devices against overloading of the

railway, short circuits, failure of current supply and exceeding of the maximum speed admissible. All control devices, including an automatic battery charger, for the lighting and control batteries in the cars, are lodged in a switchboard frame, which, when completed, was submitted to rigorous tests before it was delivered to the railway.

The remote control of the cars is not carried out by means of a multi-wire overhead line, as was deemed necessary in earlier funiculars, but by means of a control wire running alongside the railway parallel to the telephone and signal wire. The overhead wires, which were ugly and expensive, are done away with here. As contact must only be established for a short time in order to start the cars, there should be no difficulty in winter, in running the railway by remote control from the cars, because even if the control wire gets coated with ice on the length between the stations this can have no effect on the automatic succession of running operations once they have been started. In case of necessity the cars can be stopped by either car conductor by means of contact to the signal wire. This is made through the contact rod secured to the front wall of the car and mentioned before. The cars are restarted again, after telephonic agreement between the two car conductors, and by means of a contact rod brought into contact with the control wire.

The haulage machinery of the funicular is not only used for remote control but for hand control by a machinist in the upper station as well. This alternative control proves useful when inspection runs are being carried out with numerous stoppages; further in case trouble develops with the remote control gear, service can be carried on by control by a machinist. It is very simple to change over from remote control to control by a machinist as only the service brake need be changed over from electro-magnetic to hand operation and the control circuit belonging to the remote control cut out. To start and regulate the haulage motor, the same controller is used as for remote control, the only difference being that instead of being regulated by a servo-motor it is regulated by a mechanical driving device. All the rest of the switchgear for automatic service is cut out so that there are, really, two quite independent driving methods.

The experience gained up till to-day goes to show that the equipment described should be most satisfactory, not only for light traffic but for handling heavy traffic peaks both in summer and winter service.

(MS 871) *E. Hugentobler. (Mo.)*

NOTES.

Tramways and broadcasting trouble.

Decimal index 621. 396. 823.

THE rapid spread of broadcasting, in the course of recent years, has set electrically operated tramways and railways a new problem to solve.

The sparking between the contact wire and the current collectors on the coaches is the cause of most annoying disturbances in wireless receiver sets and the problem of the elimination of this trouble is one of importance especially to tramways running in urban districts.

Tests carried out in Switzerland by the authorities in conjunction with the railways have proved clearly that broadcasting trouble is, definitely and to all purposes, completely eliminated by using carbon instead of aluminium, copper or steel for the contact pieces. Carbon sliding on copper gives rise to very few high-frequency perturbation voltages and also saves the contact wire. The objection has, often, been raised that carbon contact pieces wear out quicker than those made of metal. However, experience gathered on various Swiss railways and on foreign railways goes to prove that, on the contrary, carbon contact pieces have a far longer life than metal ones, on condition that the contact wire be well polished, first, and that metal contact pieces be eliminated from the line, altogether, as they diminish the polish of the contact wire. Thus, for example, carbon contact pieces used simultaneously with metal ones last for 12,000 kilometres while if used with a polished contact wire they can last for 100,000 kilometres.

Very successful results in eliminating the trouble in receiving stations were attained by using a pantograph type of current collector equipped with carbon contact pieces. A pantograph type of current collector has the advantage of being a more satisfactory current gatherer then one of the bow type. Excellent contact conditions between contact piece and contact wire are created which are, practically, impervious to the impulses imparted to the collector by the coach, this being due to springs exercising a vertically upward thrust on the bow piece proper, on the mobility of the scissor framework and to the light construction which is combined with great transversal rigidity.

During recent years, tests were carried out, at Brown Boveri's suggestion, by the Swiss Institute of Engineering

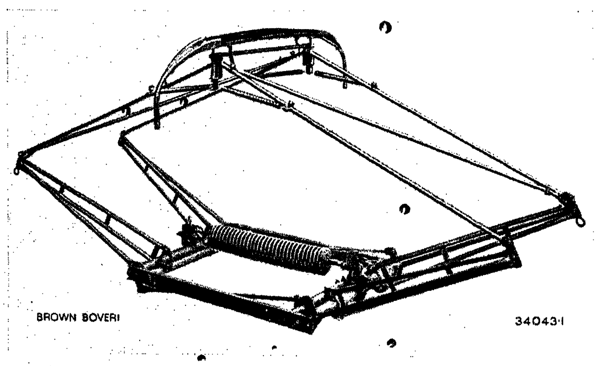

Fig. 1. — View of one of the 183 pantograph current collectors with carbon contact pieces delivered to the Basel Tramways and to the Birseck Railway.

and the General Post Office Authorities, Berne, in collaboration with the Basel Tramways, with a view to eliminating as far as possible wireless receiving set trouble. During these investigations, Brown Boveri pantograph current collectors with carbon contact pieces were tried out. The excellent results of the said tests caused the Basel Tramways and the Birseck Railway, a Basel local line, to replace the bow type of current collector in use by light pantograph current collectors with carbon contact pieces. These collectors are characterized by light construction, transversal rigidity due to suitable design, little friction in the articulations and excellent flexibility of the contact pieces in clinging to the contact wire [1]. Fig. 1 shows a general view of the pantograph current collector which only weighs about 135 kg and is only slightly heavier than the ordinary bow-type collector.

(MS 881) *O. Gysin. (Mo.)*

Substituting a machine-tool motor for a belt in the drive of a circular saw.

Decimal index 621.34:621.934.

MACHINE tools for wood working operate at high cutting speeds and are, therefore, especially suitable for direct drive by fast-running electric motors. If the tool — the saw blade of a circular saw for example — is mounted on the shaft end of the motor, a unification of tool and drive is attained which could hardly be improved on. It is, of course, essential that the motor should fulfil the requisite conditions for this kind of assembling, as regards overall dimensions and shape.

The superiority of direct drive to belt drive is most strongly marked by a comparison between a modern and an old plant, such as the one illustrated in Figs. 1 and 2.

[1] The advantages of the design developed by Brown Boveri are explained in more detail in the November number of this Review of the year 1928.

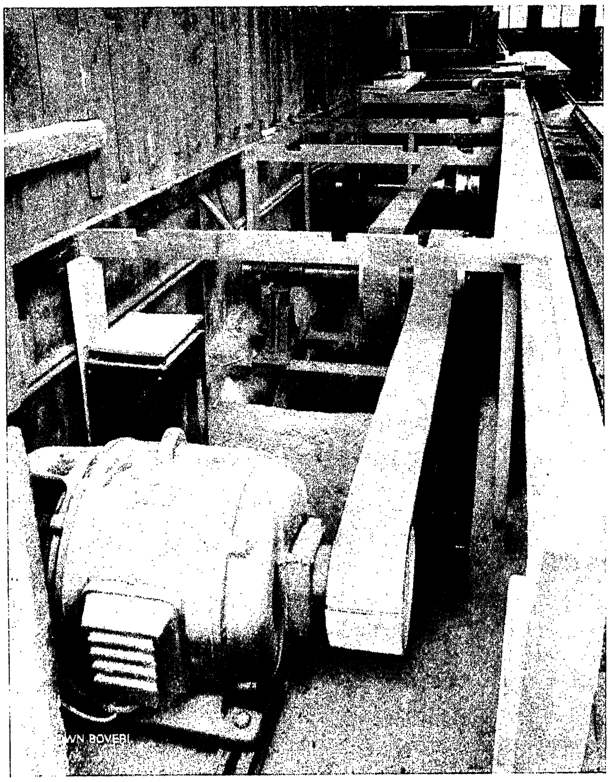

Fig. 1. — Circular saw for log trimming layout with drive by an 11-kW motor.

This is a circular saw for trimming logs in a carpentry shop, which was formerly driven by belt. At the time this plant was built the idea was prevalent that a circular saw had to have a *flexible* drive and, therefore, should be driven by belt and not directly. The motor used was of the slip-ring type, 11 kW, at about 1500 r. p. m. which speed was stepped up to 2150 r. p. m.

A circular-saw motor of Type KK 52a, of 5·5 kW output at 3000 r. p. m. has now been installed, in place of the circular-saw shaft, with pulley and bearings. The saw blade is direct-mounted on the shaft end of the motor. The head room required by the new motor is so small, that it could be mounted in place of the old shaft and bearings without requiring any serious alterations to the plant. Thanks to the high stalling torque of the Brown Boveri tool motors, it was feasible to use a motor here of a considerably lower rating than that of the former one. The new motor is completely enclosed and, therefore, pro-

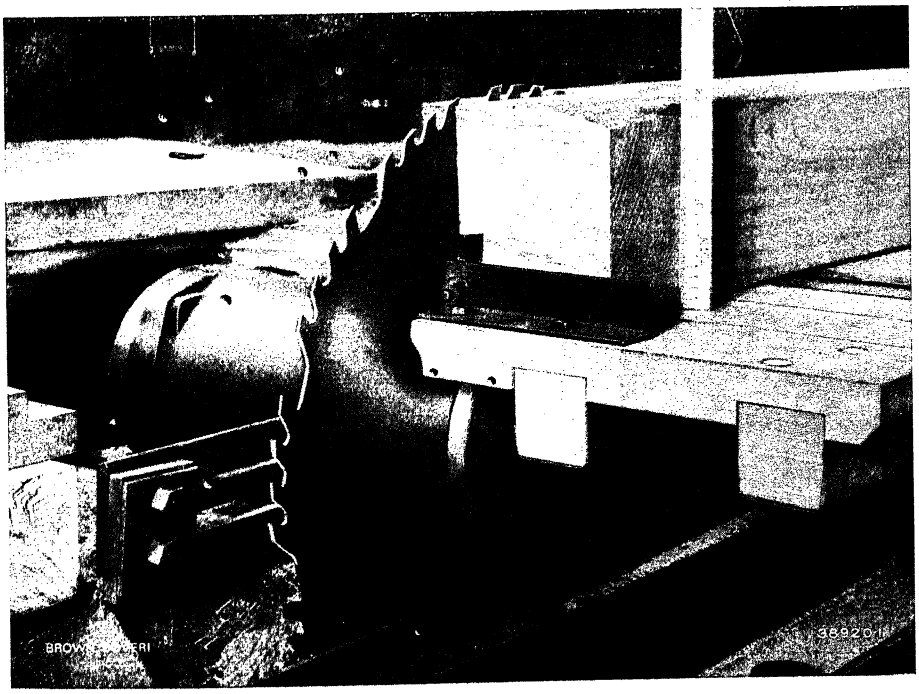

Fig. 2. — The same saw as in Fig. 1 but with the new drive by a 5·5-kW tool motor.

railway, short circuits, failure of current supply and exceeding of the maximum speed admissible. All control devices, including an automatic battery charger, for the lighting and control batteries in the cars, are lodged in a switchboard frame, which, when completed, was submitted to rigorous tests before it was delivered to the railway.

The remote control of the cars is not carried out by means of a multi-wire overhead line, as was deemed necessary in earlier funiculars, but by means of a control wire running alongside the railway parallel to the telephone and signal wire. The overhead wires, which were ugly and expensive, are done away with here. As contact must only be established for a short time in order to start the cars, there should be no difficulty in winter, in running the railway by remote control from the cars, because even if the control wire gets coated with ice on the length between the stations this can have no effect on the automatic succession of running operations once they have been started. In case of necessity the cars can be stopped by either car conductor by means of contact to the signal wire. This is made through the contact rod secured to the front wall of the car and mentioned before. The cars are restarted again, after telephonic agreement between the two car conductors, and by means of a contact rod brought into contact with the control wire.

The haulage machinery of the funicular is not only used for remote control but for hand control by a machinist in the upper station as well. This alternative control proves useful when inspection runs are being carried out with numerous stoppages; further in case trouble develops with the remote control gear, service can be carried on by control by a machinist. It is very simple to change over from remote control to control by a machinist as only the service brake need be changed over from electro-magnetic to hand operation and the control circuit belonging to the remote control cut out. To start and regulate the haulage motor, the same controller is used as for remote control, the only difference being that instead of being regulated by a servo-motor it is regulated by a mechanical driving device. All the rest of the switchgear for automatic service is cut out so that there are, really, two quite independent driving methods.

The experience gained up till to-day goes to show that the equipment described should be most satisfactory, not only for light traffic but for handling heavy traffic peaks both in summer and winter service.

(MS 871) *E. Hugentobler. (Mo.)*

NOTES.

Tramways and broadcasting trouble.

Decimal index 621. 396. 823.

THE rapid spread of broadcasting, in the course of recent years, has set electrically operated tramways and railways a new problem to solve.

The sparking between the contact wire and the current collectors on the coaches is the cause of most annoying disturbances in wireless receiver sets and the problem of the elimination of this trouble is one of importance especially to tramways running in urban districts.

Tests carried out in Switzerland by the authorities in conjunction with the railways have proved clearly that broadcasting trouble is, definitely and to all purposes, completely eliminated by using carbon instead of aluminium, copper or steel for the contact pieces. Carbon sliding on copper gives rise to very few high-frequency perturbation voltages and also saves the contact wire. The objection has, often, been raised that carbon contact pieces wear out quicker than those made of metal. However, experience gathered on various Swiss railways and on foreign railways goes to prove that, on the contrary, carbon contact pieces have a far longer life than metal ones, on condition that the contact wire be well polished, first, and that metal contact pieces be eliminated from the line, altogether, as they diminish the polish of the contact wire. Thus, for example, carbon contact pieces used simultaneously with metal ones last for 12,000 kilometres while if used with a polished contact wire they can last for 100,000 kilometres.

Very successful results in eliminating the trouble in receiving stations were attained by using a pantograph type of current collector equipped with carbon contact pieces. A pantograph type of current collector has the advantage of being a more satisfactory current gatherer then one of the bow type. Excellent contact conditions between contact piece and contact wire are created which are, practically, impervious to the impulses imparted to the collector by the coach, this being due to springs exercising a vertically upward thrust on the bow piece proper, on the mobility of the scissor framework and to the light construction which is combined with great transversal rigidity.

During recent years, tests were carried out, at Brown Boveri's suggestion, by the Swiss Institute of Engineering

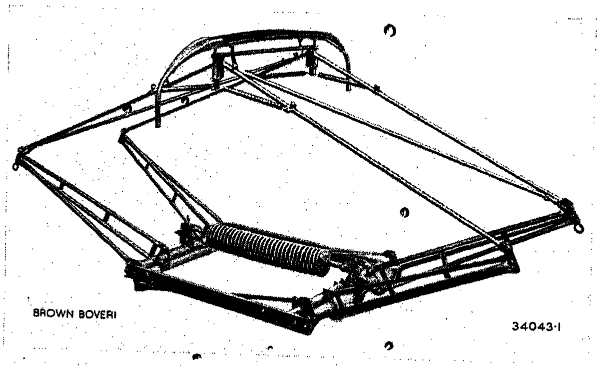

Fig. 1. — View of one of the 183 pantograph current collectors with carbon contact pieces delivered to the Basel Tramways and to the Birseck Railway.

and the General Post Office Authorities, Berne, in collaboration with the Basel Tramways, with a view to eliminating as far as possible wireless receiving set trouble. During these investigations, Brown Boveri pantograph current collectors with carbon contact pieces were tried out. The excellent results of the said tests caused the Basel Tramways and the Birseck Railway, a Basel local line, to replace the bow type of current collector in use by light pantograph current collectors with carbon contact pieces. These collectors are characterized by light construction, transversal rigidity due to suitable design, little friction in the articulations and excellent flexibility of the contact pieces in clinging to the contact wire [1]. Fig. 1 shows a general view of the pantograph current collector which only weighs about 135 kg and is only slightly heavier than the ordinary bow-type collector.

(MS 881) *O. Gysin. (Mo.)*

Substituting a machine-tool motor for a belt in the drive of a circular saw.

Decimal index 621.34 : 621.934.

MACHINE tools for wood working operate at high cutting speeds and are, therefore, especially suitable for direct drive by fast-running electric motors. If the tool – the saw blade of a circular saw for example – is mounted on the shaft end of the motor, a unification of tool and drive is attained which could hardly be improved on. It is, of course, essential that the motor should fulfil the requisite conditions for this kind of assembling, as regards overall dimensions and shape.

The superiority of direct drive to belt drive is most strongly marked by a comparison between a modern and an old plant, such as the one illustrated in Figs. 1 and 2.

[1] The advantages of the design developed by Brown Boveri are explained in more detail in the November number of this Review of the year 1928.

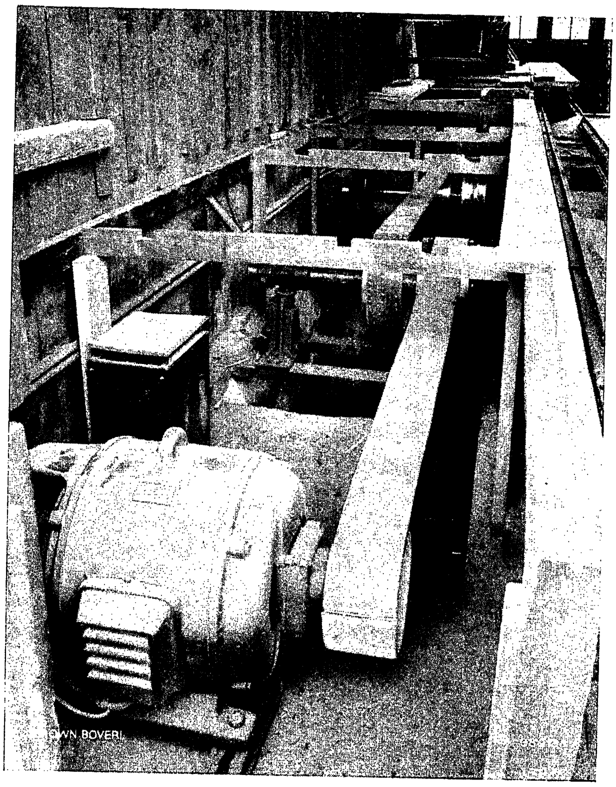

Fig. 1. — Circular saw for log trimming layout with drive by an 11-kW motor.

This is a circular saw for trimming logs in a carpentry shop, which was formerly driven by belt. At the time this plant was built the idea was prevalent that a circular saw had to have a *flexible* drive and, therefore, should be driven by belt and not directly. The motor used was of the slip-ring type, 11 kW, at about 1500 r. p. m. which speed was stepped up to 2150 r. p. m.

A circular-saw motor of Type KK 52a, of 5·5 kW output at 3000 r. p. m. has now been installed, in place of the circular-saw shaft, with pulley and bearings. The saw blade is direct-mounted on the shaft end of the motor. The head room required by the new motor is so small, that it could be mounted in place of the old shaft and bearings without requiring any serious alterations to the plant. Thanks to the high stalling torque of the Brown Boveri tool motors, it was feasible to use a motor here of a considerably lower rating than that of the former one. The new motor is completely enclosed and, therefore, pro-

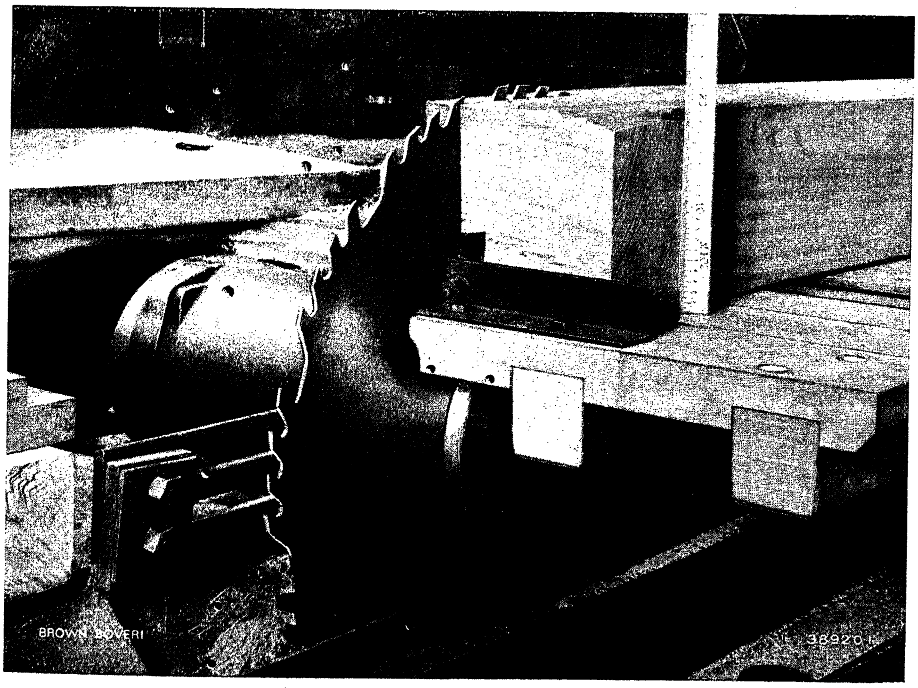

Fig. 2. — The same saw as in Fig. 1 but with the new drive by a 5·5-kW tool motor.

tected against dust and shavings, while the former one was of open design.

The useful output of the saw has been considerably raised, quite apart from the advantages which result from space gained, elimination of a transmission gear, greater reliability due to the completely enclosed motor design, simpler attendance owing to their being no rotor starter and finally, cheaper running costs. With the old flexibly driven plant, the speed fell off whenever an overload had to be met, such as occurs when a hard zone in the wood has to be negotiated, with the result that the operator instinctively slowed down the feed. The new circular saw motor, with its high stalling torque, attacks the heaviest overload duties without speed diminution and overcomes them in its stride. The feeding speed can be maintained without consideration of load fluctuations. Further, owing to the vibrationless running of the direct drive, high speeds are possible which means that the same circular saw does heavier cutting work and produces more.

The new drive has allowed of reducing service costs as there is no outlay for renewing belting, less attendance necessary and, chiefly, as there are no transmission losses. The new motor of lower rating is better utilized electrically and works more economically than the former one which was twice as powerful, because the latter was very imperfectly utilized. The losses are, at least, 1 kW lower which with a six-hours day work means a saving of 1800 kWh annually. The utilization of a tool motor of lower rating has, therefore, been very advantageous as it has meant more work done, less losses and less attendance.

(MS 884) *M. Fitz. (Mo.)*

The new textile mill at Bakirköy near Istanbul.

Decimal index 677 (496).

THE new textile mill for the manufacture of cotton goods, built at Bakirköy near Istanbul, is the first of the textile plants included in the Turkish Government's Five-Year Plan. The mill took less than a year to build and it was opened, in the presence of the authorities, in August, 1934. There is an existing mill with 3600 spindles which adjoins the new one; the latter contains 6000 spindles and 220 looms as well as bleaching, dyeing and finishing plants. The whole layout is extremely practical, the rooms being well lit and airy, while allowing of easy supervision of the machinery. The latter was, chiefly, delivered by Swiss firms. Some interesting features of the electric equipment by Brown, Boveri & Co., Ltd., Baden, are described, herewith.

For a model plant, such as this one, there could be no question of any other than individual drive for each machine, a principle which has been applied here throughout, with the exception of two motors used to drive carding-machine sets. In all, 360 motors were required with a total output of 620 kW. Batteries of cast iron power-distribution boxes and cables convey three-phase current at 50 cycles, 500 V to the motors. Most of the motors are of the squirrel-cage type, the loom motors being totally enclosed with natural cooling and the others totally enclosed with external-

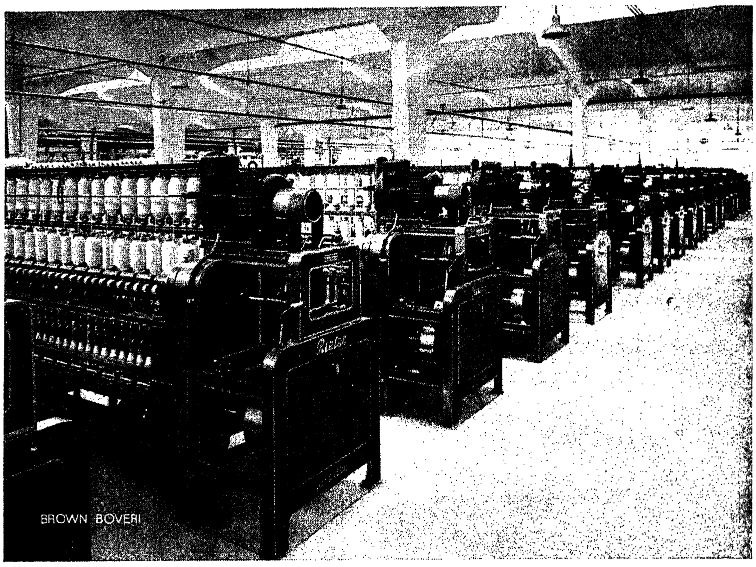

Fig. 1. — Step-pulley drive of ring spinning frames by means of squirrel-cage motors with external fan cooling.

fan cooling, a design which is becoming more and more popular in textile plants. This motor design prevents the dust prevalent in spinning mills from reaching the interior of the motors; attendance is thus limited to cleaning the exposed surfaces from time to time. The design in question protects the motor against the deleterious effects of warm, humid air saturated with corrosive vapours such as are met with in bleaching and dyeing plants, the protection being enhanced by a protective coating of paint given to the motor both inside and outside while the windings are made with an insulation very impervious to damp.

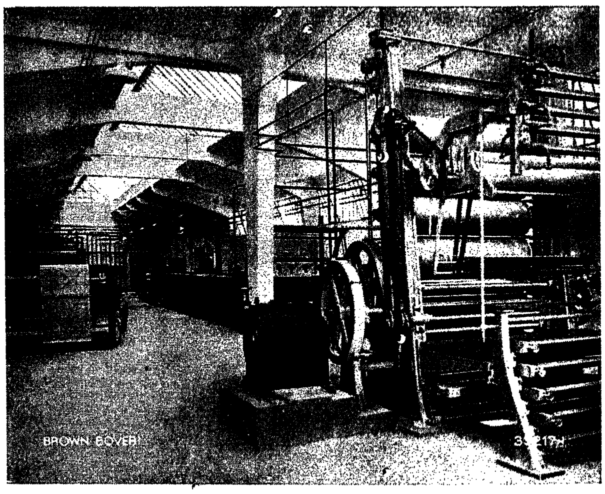

Fig. 2. — Variable-speed drive of a universal calender by means of a shunt commutator motor, 13 kW. Stentering frames with push-button control are seen in the background.

Very happy results attended the efforts already discernable when the plans were made to make the driven machine and its drive into a single unit. In all cases where the driving motor could not be built on to or built into the driven machine, short axial spacing was attained by using gear drive, while direct coupling was made possible even with slow-running machines such as ceiling reels by using motors having built-in reduction gears. The loom motors are built into the Rüti looms and drive the latter through slip couplings, according to the arrangement for gear drives which has given such good results in many plants. The loom switch is connected to the control rod. The ring spinning frames are equipped with step-pulley drive for two speeds, the motor being placed on the headstock of the frame (Fig. 1). No variable speed drives by commutator motors are used here, as only uniform coarse yarn is made.

The variable-speed drives of a number of finishing machines which work at variable speed should be mentioned. There was no question of using old fashioned speed-regulating devices such as conical pulleys etc. and shunt commutator motors were chosen, which give much more satisfactory and economical speed regulation by brush displacement. A number of machines have speed regulation by hand wheel, this being the case for the universal calender (Fig. 2); while the main drive of the stentering frame is fully automatic, by push-button control from various points, so that all the operations of this big machine, as well, can be regulated with ease and perfect certainty. These variable speed drives have again shown themselves to be extremely adaptable and to be the most suitable for the complete economic utilization of the finishing machines driven.

(MS 885) *H. Wildhaber. (Mo.)*

Electrically driven floor cleaners.

Decimal index 621. 34 : 687. 976.

THE illustration shown here is of a "Universal floor cleaner with dust aspirator" by the firm of Suter-Strickler and Sons of Horgen (Switzerland). It is equipped with a single-phase Brown Boveri motor to be connected up to lighting systems.

The motor is of especially powerful design, because the machine is intended for cleaning and polishing the floors of big halls and plants of every description. Despite the very high torque developed by the motor at starting, the starting current is relatively low and for this reason, a 10-A fuse is ample for the protection of a 220-V lighting system when it is supplying the cleaner. The starting commutator, which only carried current momentarily during the starting-up process, is short-circuited by a simple and powerful centrifugal switch as soon as the motor has reached full speed. From this moment, the motor runs practically independently of the load torque, at a constant speed of about 1450 r. p. m.

The shaft runs in ball bearings, the grease filling of which suffices for a year. The rotary switch for controlling the motor is mounted over the terminal opening in the housing and is protected by a stout cast-iron cylinder. A bolt is screwed into the upper bearing cover on which the cable drum can be placed when the machine is put away. By simple change-over of connections on the terminals

Fig. 1. — 1-H. P. single-phase motor built on to a floor cleaner.

two voltage ranges can be set to, namely 110—125 and 220—250 V (50 cycles), so that one and the same motor can be used for nearly every lighting-system voltage encountered.

These motors have proved their worth in service. All parts carrying current are protected against accidental contact. Attendance is of the simplest and no special attention is required, as the only parts subject to wear — commutator and brushes—only carry current during the starting period and hardly wear down at all.

(MS 886) *S. Hopferwieser. (Mo.)*

The small automatic hydro-electric power station for the Jungfrau Hotel, Eggishorn (Canton Valais).

Decimal index 621. 311. 21. 078 (494).

SMALL hydro-electric power stations are used to supply power to localities, farms, mountain hotels, etc. in remote regions which cannot be connected to a supply system, either because there is none in the vicinity or because a connecting line thereto would be too expensive with regard to the small amount of power required. Obviously, plants of this kind can only be run economically if they are practically automatic and are simple in design.

When there is water power in small or moderate quantities available, it is understandable that the chance to generate the requisite electric power is seized on. This is the solution adopted by the Jungfrau Hotel on the Eggishorn in Canton Valais (Switzerland). This hotel built its own power plant purchasing the electrical equipment from Brown Boveri.

The generating set is composed of a Pelton wheel by the A.-G. der Maschinenfabrik von Theodor Bell & Co. in Kriens-Lucerne. It has a standard rating of 94 H.P. at 1250 r.p.m., the head being 170 m; it drives a D. C. generator 63 kW

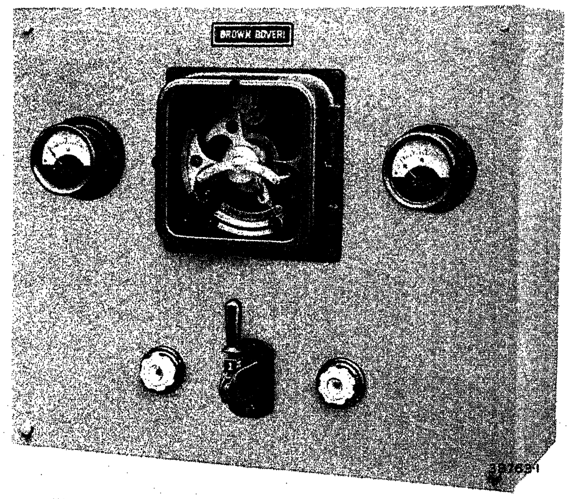

Fig. 1. — Wall panel with built-on automatic quick-acting voltage regulator for a small automatic hydro-electric power station.

at 230 V, which is flexibly coupled to the turbine. In order that service may be as simple as possible, and so as to keep the price of the plant low, the turbine has no speed regulator. Its speed varies according to the load between 1250 and about 2200 r. p. m. The water discharge is very dependent on the rain fall and it varies between 50 and 20 litres per second. The flow of water to the turbine is, therefore, regulated from time to time, according to the discharge volume available.

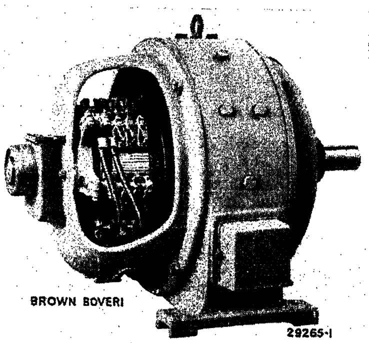

Fig. 2. — D. C. generator of standard type.

As the voltage fluctuations of the generator would be about proportional to its speed, a quick-acting automatic Brown Boveri regulator is used which holds the voltage constant at 230 V within the speed limits given above.

A small panel for mounting on a wall was delivered to hold the necessary switchgear. Apart from the quick-acting regulator, this comprises a voltmeter, an ammeter, a two-pole switch and two fuses. The panel is shown in Fig. 1 while Fig. 2 shows the generator.

The plant has been running for about two and a half years and operates to the complete satisfaction of the owners.

(MS 888) *A. Caprez. (Mo.)*

The new generators in the Hagneck Electric Power Station.

Decimal index 621.313.322.2 (494).

THE Hagneck Electric Power Station is one of the oldest hydro-electric power houses in Switzerland. It was built between 1897 and 1900 by the Motor Company, Baden, practically at the same time the Spiez power house was built. These two plants were then taken over by the Kander and Hagneckwerke Company and, later on, passed into the hands of the Bernische Kraftwerke Company.

The Hagneck power house utilizes a head of between 5·5 and 9 m on the Aare Canal, between Aarberg and the Lake of Bienne; the Aare Canal, itself, having been created in the years 1873/1900 and forming part of the work carried out to regulate the water flow from the Jura Mountains. The Hagneck power house is located at a short distance above the mouth of the canal into the Lake of Bienne.

The station was equipped with four vertical-shaft generating sets each of 1600 H.P. and with a fifth set of 1900 H.P. The turbines consisted each of four Francis-type turbines placed one above the other, the speed being 100 r.p.m. The generators, direct-coupled to the turbines, were built for 8000 V, 40 cycles, 4 being of 1400 kVA and one of 1700 kVA output. Each generator had its own exciter which was a vertical-shaft machine driven through gearing from the turbine shaft. All five generators and exciters were built by Brown, Boveri & Co., Baden.

In the years 1931/33, the power house was completely transformed. Three propeller-type turbines and one Kaplan-type turbine built by the Ateliers des Charmilles Co., Geneva, were put in, in the place of the Francis-type turbines. These new turbines develop under an 8·8 m head an output of 3300 H.P. at 187 r. p. m., the run-away speed being 480 r. p. m.

The site of the former fifth generating unit is left empty, for the present.

The four new generators, also built by Brown, Boveri & Co., Baden, are direct-coupled to the turbines. The illustration on the cover of this number shows their layout in the machine-room. These generators are built for a continuous rating of 3400 kVA at 16,000 to 17,600 V terminal voltage and a power factor between 0·7 lagging and 0·8 leading; the speed being 187 r. p. m. and the frequency 50 cycles.

The stator is in two parts. The thrust bearing is mounted on the upper spider. It has to carry the weight of the complete rotating part and that of the head of water, making 109,000 kg in all. The weight of the pole wheel alone is 25,600 kg, it has a diameter of 3800 mm and a flywheel effect of 200 tm^2. The exciter is mounted above the thrust bearing. The lower spider carries a braking device actuated by compressed air. A set of supporting bolts allows of supporting the weight of the rotor when inspection of the thrust bearing is carried out. The generators are of completely-enclosed design. The cooling air is drawn in from below through ducts lodged on an intermediate floor and, after passing through the machine, it is expelled to outer atmosphere.

Two generators were put into regular service in the autumn of 1932 and the other two in the spring of 1933.

This transformation of the station brought up the total output from 7300 kVA to 13,600 kVA, and, therefore, nearly doubled it, while the volume of water passing through the four new turbines remains the same as in the old five units as well as the head it works under.

(MS 889) *G. Fisler. (Mo.)*

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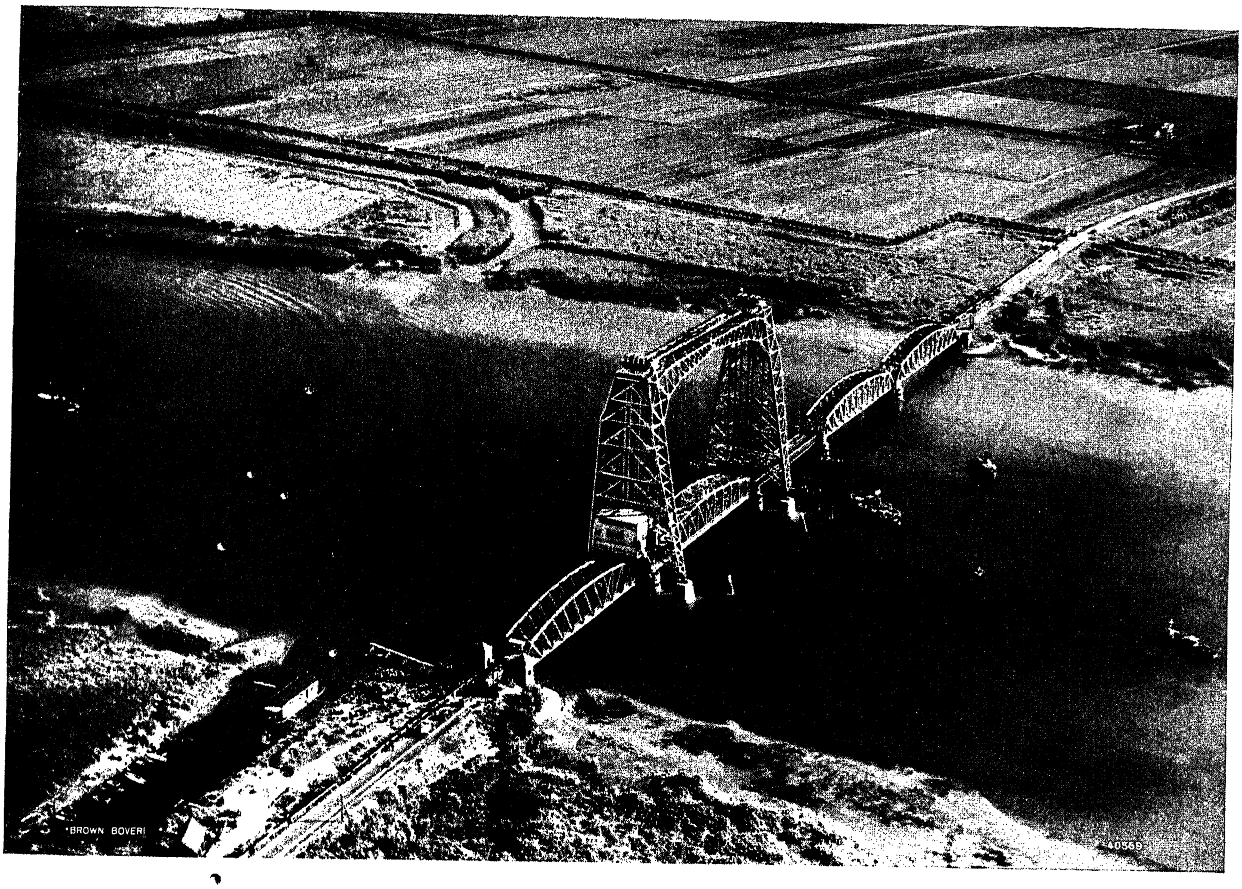

GENERAL VIEW OF THE LIFT BRIDGE AT BARENDRECHT (HOLLAND).
Aerial view (Copyright KLM).

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THE LIFT BRIDGE OVER THE OUDE MEUSE NEAR BARENDRECHT.

Decimal index 624.82 (492).

ONE of the biggest lift bridges in Europe has been erected in the vicinity of the village of Barendrecht, in Holland.

This lift bridge is shown in the aerial view on the cover of this publication as well as in the drawing given in Fig. 1. When raised, the bridge allows big vessels to pass, the opening being 50 m wide and 45 m high. The bridge was designed by Mr. de Klerk, engineer, who was also in charge of the erection work. The main data on this plant is given in the following table from which a good idea of the dimensions of the bridge is obtained.

Main spans	68·650	m
Lift	40·335	m
Total weight of movable platform with foot-way	514	t
Heaviest snow load to be reckoned with	25	t
Total counter-weights	540	t
Hoisting speed with the main drive	0·705	m/sec
Output of main hoisting motor .	150	kW
Hoisting speed with the auxiliary drive	0·1	m/sec
Output of auxiliary hoisting motor	34	kW

The bridge is of the truss type and balanced by two 270-ton counter-weights. The machine house is placed on one side of the bridge and divided into two chambers, namely:— the machine-room proper and the operating room. The first room contains the winding gear for raising the bridge, the motors and the brakes, as well as the transformers and the distribution plant; the second room projects over the fairway and thus gives the bridge operator a commanding view of the bridge platform and the waters of the fairway. This chamber contains the controlling and supervising apparatus.

The *mechanical organs* of the hoisting gear were designed and built by the firm of Duyvis, Koog aan de Zaan, in collaboration with Brown, Boveri & Co., Ltd.

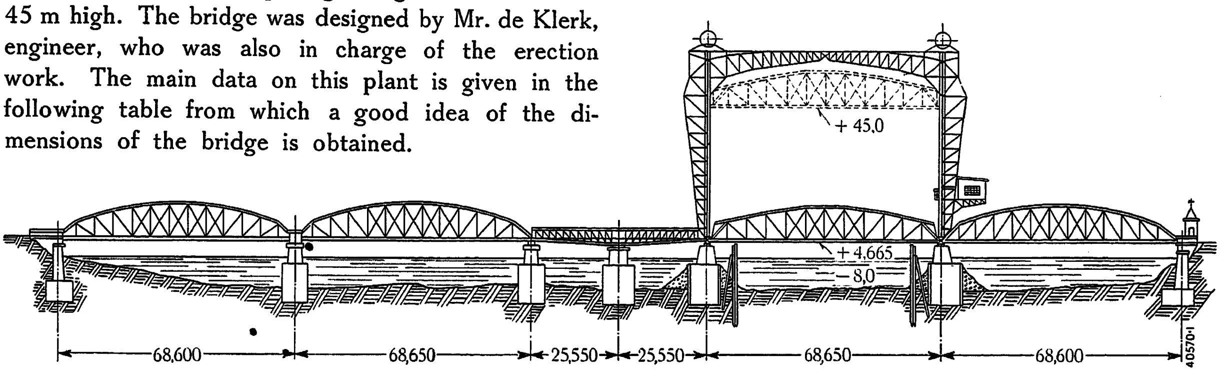

Fig. 1. — General layout of the lift bridge over the Oude Meuse near Barendrecht.
Dimensions in metres.

The two hoisting drums which have a winding diameter of 1800 mm, the shaft of the reduction gear, which drives them, and the whole braking equipment are carried by stout underframes; the same applies to the driving (hoisting) motors with their own reduction gears and to some accessory devices. Each drum has a rim of teeth on its outside end, these teeth are driven by the common through-going shaft of the reduction gear mentioned above, by means of pinions (Fig. 2). The main driving motor drives the shaft of the reduction gear through a spur-wheel gear mounted at the centre of the shaft length. The high-speed shaft of the reduction gear is coupled at one end to the main motor through a flexible coupling while its other extremity carries a coupling of the engage and disengage type by means of which the auxiliary motor can be coupled up or uncoupled. Under ordinary service conditions the hoisting gear is driven by the main motor while the auxiliary motor is uncoupled and stationary. Exceptionally, that is to say if the main motor is not working, the drive is carried out by the auxiliary motor; in this case, the main

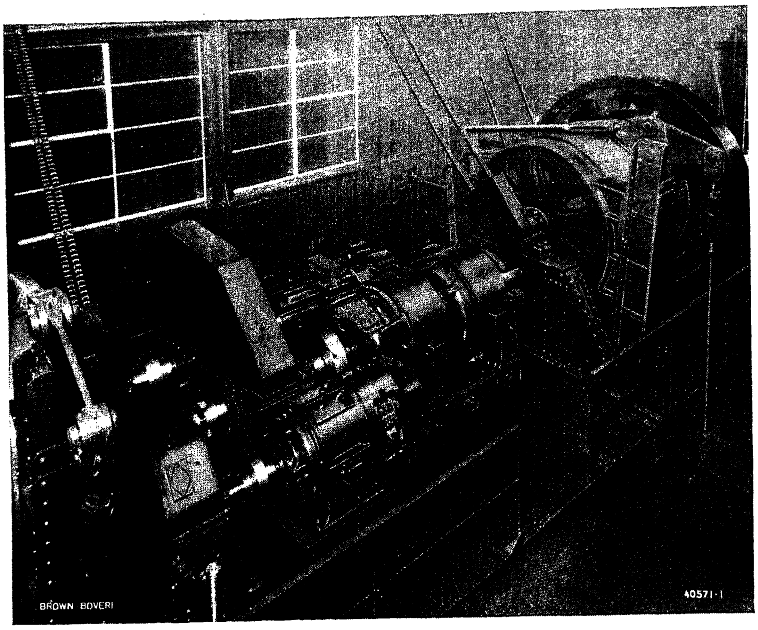

Fig. 2. — Drive of hoisting gear with main and auxiliary drives.

motor revolves empty. Each drum has its own braking device composed of an exceptionally powerful shoe-type brake.

The drive of a lift bridge of these dimensions makes very exceptional demands on the electrical equipment. The latter must be absolutely reliable and ready to operate at any moment. On account of the very big masses to be moved, the drive must have perfect control of the load over the whole lift travel and in both senses of displacement; it must ensure smooth starting, a very wide range of speed regulation with no speed steps if possible and efficient electric braking — a very important factor, in this case.

The *single-phase commutator motor* of Brown Boveri design meets all the requirements inherent to the drive of a lift bridge of this type; further, one spare motor alone constitutes, in itself, a complete spare unit. Starting and speed regulation of the single-phase commutator motor is carried out by closing the stator circuit and by displacing the brushes on the commutator and this without using resistances etc., that is to say without loss of power. The speed can be regulated over a wide range and, practically, down to zero, by brush displacement. By far the most valuable quality, however, of a motor of this type for a drive of this description resides in its capacity to provide controllable and powerful electric braking, by very simple switching.

The main motor was built as a double machine, that is to say, it is composed of two stators secured to a common bedplate and two rotors on a common shaft. The stator windings of both half-motors are connected up together in Scott connections, so that the three phases of the three-phase system are, practically, evenly loaded. The motor was wound for an output of 150 kW at a 30-minutes rating, 380 V, 50 cycles. The synchronous speed is 600 r. p. m. but when raising or lowering the bridge apron, if unencumbered by snow, the motor operates at 720 r. p. m., corresponding to a hoisting speed of 0·705 m/sec. When a load of snow is carried, the speed of the motor is set to about 375 r. p. m., which corresponds to the heavier load and greater strain on the mechanism. The minimum starting torque developed by the motor is 800 mkg, which is approximately 3·8 times its rated torque.

As compared to the main motor, the auxiliary motor is of low output, it being built for 34 kW at a 30-minutes rating. The synchronous speed is 1000 r. p. m. and the rated working speed, with or without snow on the bridge apron, is 1160 r. p. m., corresponding to a hoisting speed of 0·1 m/sec.

The connections of the whole plant are shown in the diagram given in Fig. 3. The control of the main motor or of the auxiliary motor is exercised through the agency of a single operating lever placed in the operating room. This operating lever is connected by rod to the brush rockers of the main and auxiliary motors in such a way that the rod can be coupled up to either motor by means of a special coupling. An electric interlock, between this coupling and the change-over lever of the engage and disengage coupling placed between the main and the auxiliary motor, is so designed that driving can only be carried out when the control rod is connected to the proper motor.

Each motor is separated from the supply system by a three-pole oil-bath switchbox, fitted with the requisite motor-protection devices. The two-switch-boxes are interlocked in such a manner that only one of them can be switched in at a time, the one in question being that of the motor which has been prepared to take over the drive. The switchgear of the two motors is controlled by a common auxiliary switch coupled to the control rod. The system of connections chosen is a so-called symmetrical travel-braking connection, that is to say, the forward-travel positions are on one side of the zero position of the operating lever and reverse-travel positions on the other. The braking positions, i. e. the braking zone for either sense of travel, is attained by bringing back the operating lever beyond the zero position

into the zone of opposite sense of travel:— thus the braking zone for the upwards movement is over on the side of the lever slot corresponding to downward travel, while that for the downward movement is on the upward travel side.

of the single-lever control stand and the excellent service-results attained therewith form the motive which led to the choice of this braking and control equipment for the present lift bridge.

The layout of the *braking gear* is also shown in the diagram of connections of Fig. 3. The service brake was designed as a compressed-air brake, which

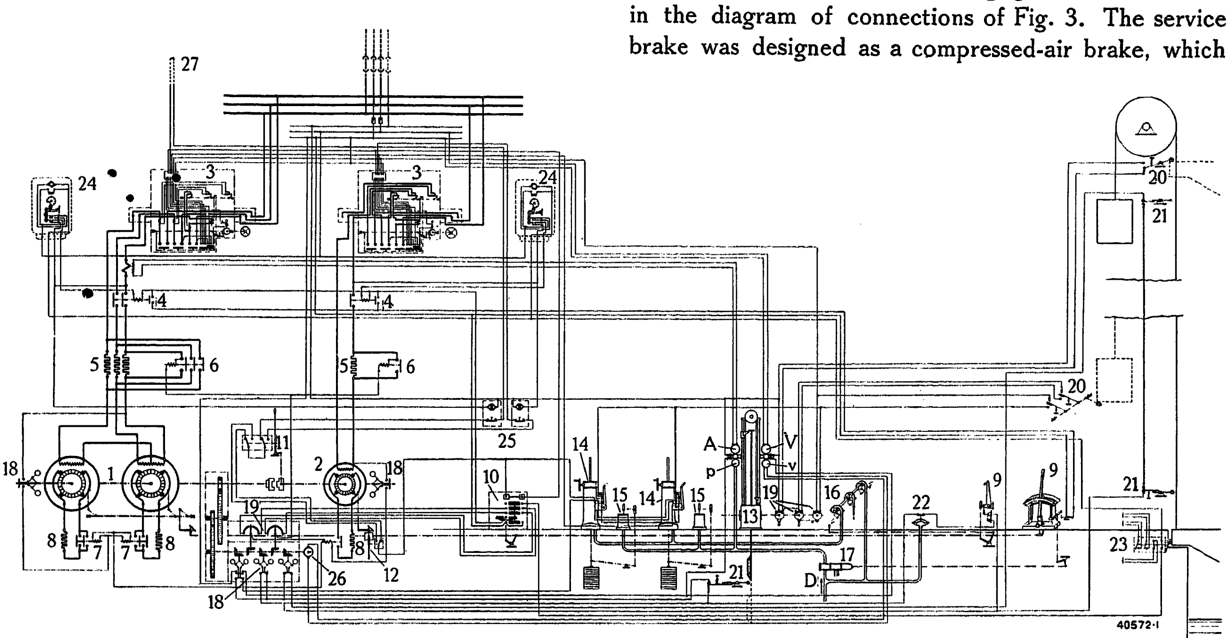

Fig. 3. — Main diagram of connections of the lift bridge near Barendrecht.

1. Main motor.
2. Auxiliary motor.
3. Switchboxes.
4. Stator contactors.
5. Braking resistances.
6. Braking contactors.
7. Contactors to limit speed of rotation.
8. Resistances to limit speed of rotation.
9. Operating stand with emergency lever.
10. Auxiliary switch.
11. Main-coupling lever with switch.
12. Rod-coupling lever with switch.
13. Depth indicator.
14. Safety brakes.
15. Service-brake cylinders.
16. Three-way valve.
17. Brake-pressure regulator.
18. Centrifugal switches.
19. Switches for reversing sense of rotation.
20. End-travel switches.
21. Speed-control switches.
22. Minimum-pressure relay.
23. Interlock switch.
24. Time relays.
25. Push-button boxes with signal lamps.
26. Inductor of tachometer.
27. Interlocking contact in change-over switch of the transformers.

D. From compressed-air container.

A device has been provided to limit the speed of the machines, as a safeguard against too fast travelling, caused by faulty control, and as a dead-man emergency device. This gear is composed of a contactor controlled by a centrifugal switch which short-circuits the brushes, in pairs, over a resistance when the highest admissible speed—105 % of the rated speed—is reached. This synchronizes the machine, which now works with the same torque, speed and characteristic as an induction motor.

Although the single-phase commutator motor allows of easy, reliable electric braking, it was indespensible, in view of the enormous weights in movement here, that an efficient and safe mechanical brake should be added. This brake is used, under ordinary conditions, as a holding brake, but it must be capable of braking down the drive dynamically, as well, at any moment and especially in an emergency. The great advantages of the braking device developed by Brown Boveri for winding-engine plants, with separate service and safety brakes, along with the advantages could be regulated. The two shoe-block brakes of the lifting drums are each actuated by a brake cylinder, the compressed air is distributed to the two brake cylinders from a single brake-pressure regulator actuated from the operating stand, so that both brakes must exercise the same braking effect on their respective drums. As said before, this service brake is chiefly used as a holding brake, that is to say to maintain the machinery at a stop once it has been braked down by electrical braking. It can, however, be used at any time to supplement the electric braking and can supplant the latter entirely, if necessary.

The third independent braking device in the plant is the safety or emergency brake. Its duty is to stop the machinery in the shortest time possible, if any kind of trouble arises in service, such as overwinding of the bridge apron, too high speed, overloading of the motors, failure of the voltage or compressed-air supply, etc., this without undue stressing of the winding gear itself, the hoisting cables, or the

framework of the bridge. The well known Brown Boveri safety brake, as opposed to other brake designs, is a purely gravity brake, so that it operates reliably independently of voltage or air pressure. It is a free fall brake, that is to say the brake weight falls without being damped down until the brake shoes are applied to the brake disc, so that braking time is reduced to a short space of time; nevertheless, braking takes place without jerks, because a powerful damping effect comes into play from the moment the brake shoes are applied; the result is that the braking pressure increases rapidly from zero up to the normal end pressure. The brake weight is equipped with an oil cataract device so that hunting and excessive stressing of the brake rod are excluded. A further advantage of this brake is its complete independence from the service brake, thus a possible disarrangement of the latter has no influence on the service reliability of the safety brake.

There are two safety brakes operating in common, one of which works on a brake shoe of each drum.

The brake weights are lifted again by compressed air, but, if necessary, can be raised by hand.

As said before, the control of the whole lift bridge, i. e. of the main or auxiliary motor and of the braking devices, is carried out from one operating stand mounted in the operating room. The whole control equipment—mechanical and electrical—is designed to the well-known single operating lever principle created by Brown Boveri. The operating stand (Fig. 4) has a single operating lever mounted in a wide slot and cradled in a joint support which allows of its being displaced lengthwise and crosswise. If the lever is displaced lengthwise in the slot the brushes are moved over the commutator of the hoisting motor which is either started, its speed changed or braked down, the motoring or braking torques of the machine being proportional to the angle of displacement of the operating lever. If the lever is displaced crosswise in the slot the brake-pressure regulator controlling the service brake is actuated, the braking pressure being about proportional to the angle of displacement. This operating stand thus allows of an operator grasping the principle of control easily and in a short time, so that the said operator is soon entirely master of the requisite movements.

Fig. 4. — Operating chamber with single-lever operating stand and depth indicator.

The operating stand carries an emergency lever which allows of applying the free fall safety brake in an emergency. This lever also allows of lifting the safety brake. Two push-button boxes mounted in close proximity allow of remote tripping of the switchboxes, which cuts off the supply of the whole plant; this, of course, causes the safety brakes to act. There are pilot lamps mounted on the push-button boxes to show the bridge operator which switchbox is switched in, that is, which motor is ready to take over the control of the bridge.

As shown in Fig. 4, there is a depth-indicator placed on one side of the operating stand showing the exact position of the bridge. This depth indicator has vertically mounted threaded spindles driven by one of the drum shafts through a connecting shaft; these spindles have travelling nuts with pointers which move up and down according to the position of the bridge and counter-weights.

Further, there is a device by means of which the last section of the upward or downward travel is shown to a bigger scale, which allows of bringing the bridge to a stop with greater safety and precision. The depth indicator is provided with two red pilot lamps and with the requisite supervisory instruments. An alarm bell is actuated near the end of the upward travel and draws the operator's attention to the necessity of lowering the speed of the bridge. Thus all supervisory devices and apparatus are concentrated in one single supervisory apparatus.

Mention should be made of the numerous safety devices and interlocks which prevent faulty manœuvring and which bring the bridge to a stop automatically in such cases. All the apparatus for this purpose is inserted in the circuit of the trip magnets of the safety brakes or in the circuit of the no-volt coils of

the switchboxes and these two circuits are so interlocked that an application of the safety brake must infallibly cause the switches to open; further, the opening of the said switches results in the application of the safety brakes.

The different *speed supervisory devices* are very important factors for perfect service. It has been said, already, that the motors are equipped with a speed-limiting device, which acts at 105% of the rated hoisting speed. A centrifugal switch is added as an additional safety device, which cuts off the whole plant at 110% of the rated speed and brings the bridge to a stop by application of the safety brakes. In order to prevent the bridge reaching its end-travel position at too high a speed, the approach speed in either sense of travel is so controlled that, if the approach speed set for is exceeded, the bridge is immediately brought to a stop. The device is composed of supervisory switches, lodged, in part, in the bridge frame proper, in part, in the depth indicator and which are opened as the bridge passes the point in question, thus opening the tripping-current circuit. There are centrifugal switches connected in parallel with the switches just mentioned, which shunt the supervisory switches as long as the speed remains within admissible limits. The whole equipment, the operating method of which is shown clearly in Fig. 3, is so adjusted that the travelling speed is reduced by 50%, 3 metres before the end-travel position is reached and is again reduced to 6% of the rated speed at 0·5 metres from the said position. There are also end-travel switches built in for the highest position of the bridge and the lowest position of the counter-weight. Similar switches are not required for the lowest bridge position, as the speed-regulating devices only allow the bridge to come to rest on its supports at a very much reduced speed (6%). Practical experience shows that the bridge comes to rest without the slightest shock which is a testimony to the efficiency of the safety devices provided.

All these safety devices assure faultless and most reliable service of the lift bridge; if left to itself, even, all safety devices work quite automatically, so that accidents are prevented in this extreme case as well. There is a device which allows of drawing the under cables taunt again once the bridge is resting on its supports. No locking gear is required to hold the bridge down on its lowest position, the bridge apron is only held down on its supporting points by the pull exercised on it by the under cables. The connections are so made that, even if faulty operations are carried out, neither motor nor cables are too highly stressed.

Of course, all signalling devices necessary for the shipping traffic and for the road traffic are provided. The connections are so made that the bridge can only be set in movement when the guard gates are closed and when the proper signals are set; on the other hand, signals and guard gates can only be operated when the bridge is in the right position. Further, the switchboard shows the exact picture of the bridge to small scale, with miniature pilot lamps which allow the operator to supervise the working of the signals exactly.

The Barendrecht lift bridge described here, has been in regular service since the end of May 1933, and has worked perfectly, in every way. The lay-out with the Brown Boveri single-lever operating stand combined with single-phase commutator-motor drive has resulted in easy and logical operating conditions, qualities which have met with general recognition.

(MS 882) *G. Rochat. (Mo.)*

SELF-PROPELLING PETROL-ELECTRIC TRUCK FOR ELECTRIC-ARC WELDING, FOR CONSTRUCTIONAL OR UPKEEP WORK ON RAILROADS.

Decimal index 625. 245. 94: 621. 791. 75.

ELECTRIC arc welding is being utilized in the most varied branches of railroad construction. One of the most important fields of application is the electric welding of rail connections, on electrically operated lines, which generally use the rails as return conductor. In order to reduce loss of power, efforts tended, from an early stage onwards, towards improving the conductivity of the rail joints by the addition of copper connecting pieces (rail bonds). These connecting pieces used to be screwed on to the rails as were, also, the earthing conductors between the poles carrying the trolley wire and the rails. Owing to the hammer blows to which the rail joints are continuously subjected by trains passing over them, the screws fixing the bonds quickly worked loose. Increased losses were the result of this and strong stray currents with all their disadvantages, such as the corrosion of water pipes etc.; while, on the other hand, badly earthed poles were a possible danger both to railway employees and to passing persons.

Later on, tests were made on the autogeneous welding of the rail bonds to the rail ends. Autogeneous welding, however, caused internal stresses to arise in the rails themselves, on account of the amount

of heat concentrated on one spot, and these tensions often caused the rails to break. For this reason, the practice was abandoned.

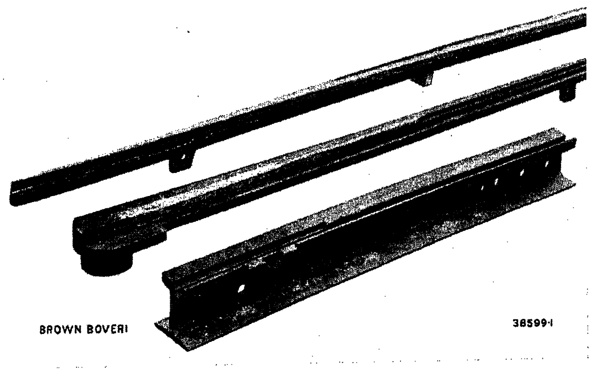

Fig. 1. — Lengths of rail repaired by means of electric-arc welding and electrically welded connecting pieces.

The last decade has seen electric-arc welding conquer this field as well as many others. This modern process makes perfectly feasible the welding of copper or iron bonds directly to the rail end, but at the base of the rail, without affecting the quality of the rail in any way whatever. The earthing conductors used on transmission-line poles and composed of copper wire of 10 mm diameter which are connected, on the one hand, to the iron transmission-line pole and, on the other, to the rail, are very amenable to electric welding. Fig. 1 shows rail bonds and rail lengths which have been repaired with the help of electric-arc welding.

In railway-bridge inspections and, especially, in strengthening railway bridges, electric-arc welding renders invaluable services. Fig. 2 shows a bridge on the Swiss Federal Railway system which has been reinforced by this method.

Within the last eight years, Brown Boveri have built a large number of welding machines driven by petrol engine and most of which are used on railway systems. Welding sets of this type make the site of the work done quite independent of outside current supply and can be used when the contact wire is under tension or dead. These sets, most of which are portable, in order to allow of road transport, are placed on trucks when intended for railway systems.

A new type of self-propelling truck was put into service lately by the Swiss Federal Railways. This truck, shown in Fig. 3, is chiefly intended for welding and metal cutting by electric arc anywhere on a line section. Further, it has to supply current to the motors of travelling cranes, compressors and drills, etc., when work is being carried out on bridges and superstructures and, during the night, it must give current for illuminating the working site. Among other duties which it fulfills are, for example, battery charging, melting of frozen water pipes, warming up of transformers and mutator cylinders, supplying current for magnetic clamping devices, etc. Further, the truck must be self-propelling in order to be used for line inspection and for the supervision of contact wires.

These manifold duties which, partly, demand a constant voltage and, partly a variable one, are performed with the help of a very simple electrical equipment the main parts of which are a generator, a traction motor and a change-over controller.

The generator is a standard welding dynamo with a falling characteristic. It is designed for a terminal voltage of 35 to 65 V and a welding current of 50 to 250 A. Drive is by a petrol engine developing 20 H.P. at 1500 r. p. m.

The voltage requisite for lighting circuits, of about 110 V, is attained by increasing the speed of the generator set to 2200 r. p. m. This is done by simply setting the speed regulator of the engine accordingly. The dynamo voltage set for is made independent of the load by means of a compound winding.

As a generator set is provided, in any case, it was obvious that the alternative available, here, of using electric drive for the car would be favoured, instead of that consisting in an ordinary gear-box drive as generally used with petrol engines.

The traction motor—a quite standard, spray-water proof series-wound machine—is suspended in the car frame and drives one of the car axles through

Fig. 2. — A bridge on the Swiss Federal Railway system, near Ziegelbrücke.
Stanchions, struts, upper bracings and roadway were all reinforced by means of electric welding.

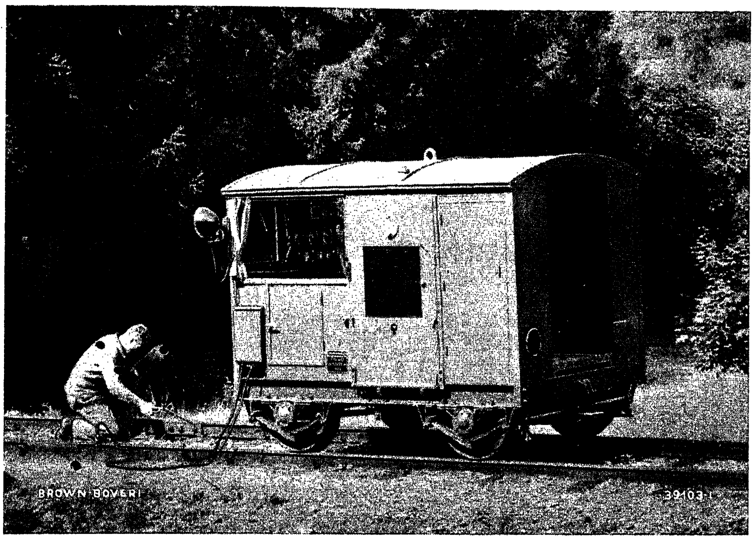

Fig. 3. — Self-propelling, petrol-electric truck for arc-welding.

a cardan shaft and worm drive. This motor is connected up directly to the terminals of the generator. For driving the car, the generator is used in exactly the same connection as for welding, that is to say with a falling characteristic. However, the speed of the generator set is also increased to 2200 r. p. m. in order to have as much power as possible available for travelling:— At this speed, the petrol engine develops 27 H.P.

The regulation of travelling speed is carried out exclusively by voltage variation with the help of the field regulator in the excitation circuit of the generator. The regulation thus obtained is, practically, without losses and very gradual, between the stationary condition and the highest speed attainable of 45 km/h. Further, this method of regulation has the advantage of requiring no extra apparatus for travelling such as controllers or starting resistances.

A small change-over controller which is built in, allows of establishing in the simplest manner the different electric connections for the various methods of utilizing the car. This controller is actuated under no current and, apart from its "off" position, has one position each for welding, for crane and lighting service and for forward and backward travelling.

In order to avoid travelling backwards over long distances, which is inconvenient on account of there being only one driver's seat, the car can be turned round at any desired point on the rails. To this end, it is equipped with a raising and rotating device which is very easy to work.

When the car was taken over, very exhaustive travelling tests and measurements were carried out. The railway authorities praised the extraordinary simplicity of the operating gear which called for no preliminary practice or skill. This is a valuable quality for a car of this type as it allows of its being run by unskilled operators.

Brown, Boveri & Co. delivered the electric equipment for welding, for crane and lighting service and for travelling. The car proper was built by the Ateliers de Constructions Mécaniques, Vevey. The utilization of the welding generator to supply the traction motor has been patented by Brown Boveri in Switzerland, France, Italy and Spain.

(MS 887) *H. Margot. A. Steinegger. (Mo.)*

THE ELECTRIC DRIVE OF GOVERNOR PENDULUMS.

Decimal index 621. 34 : 621. 248.

THE oil-pressure governors of hydraulic turbines generally require two drives, independent of one another, one for the oil pump and one for the governor pendulum. When the turbine is of the horizontal shaft type, this can be carried out easily, by belts driven from the main shaft. Drives of this kind, however, present some difficulties when applied to vertical-shaft turbines, owing to the angle through which the belt must pass between the vertical turbine shaft and the horizontal governor shaft. Up till now, bevel gears were added, which drove a horizontal shaft on which the oil-pump pulley and governor-pendulum pulley were mounted. This solution has several defects, however, namely, the space required, together with the condition that the location of the governor is still dictated by that of its drive, the necessary supervision and, frequently, the disagreeable noise caused by the bevel gear. It may also happen that vibration and impacts of the gear teeth are transmitted to the pendulum, which is very sensitive; this may even cause the servomotor to act. The impacts of the teeth are especially perceptible when the oil pump runs empty and the drive is practically under no load, except for whatever small power input is required to drive the pendulum itself. An elastic coupling is inserted on the horizontal shaft to suppress this defect, but does not entirely prevent the impacts of the teeth being transmitted to the pendulum. In belt drive, the slip must be as uniform as possible, a

result attained with the help of jockey pulleys; these, however, increase the wear of the belt, and a break in the belt may have the gravest consequences here.

For these reasons, the belt drive of governor pendulums is now being superseded by electric drive by motors. There is no difficulty, here, as regards the drive of the oil pump. The motor can be fed from any available source of current and voltage or speed fluctuations exercise no influence. If the current is cut off momentarily, an emergency reserve can be formed by providing air-cushion chambers.

Conditions are not so simple for the drive of the pendulum, because the speed of the pendulum motor must vary in exact proportion to that of the turbine. Under all circumstances, a break in the current supply must be avoided, as a drop in pendulum speed immediately causes the turbine guide blades to open further. The speed of the turbine then rises, as the pendulum no longer acts against this, and the turbine will, certainly, run away, unless some reliable safety device against this emergency is added. As the speed of the motor is to be dependent on that of the turbine, the motor must, obviously, not be supplied from an independent source but be connected up to the generator coupled to the turbine or to an auxiliary generator driven by the turbine.

According to what has been said here, the following solutions are to be considered:— a transformer is placed close to the terminals of the main generator, and the «pendulum motor» is connected to it. An ordinary squirrel-cage motor can be used for this. Built-in type motors are especially suitable, here, as they can be built together with the governor, so that the whole forms a constructive unit. Although only about $^1/_4$ H. P., at the most, is required to drive the pendulum, a motor of about 0·75 kW is usually chosen, in order to reduce the slip to a minimum. It is true that this means that the motor absorbs a relatively heavy starting current which must be taken into account when dimensioning the transformer and its fuses. It is very important that the motor should start easily. The turbine builders generally demand that it should start up under 60 % of the rated voltage, so that it has started when the main set has reached 70 % of its rated speed. The output of the motor must still suffice when the voltage has dropped to 50 % of its rated value.

Although the possibility of trouble occurring in such a simple device is very remote, as, for example, a stoppage due to the fuses on the primary side of the transformer blowing out owing to a short circuit in the winding of the latter or the tripping of the thermal release of the switchbox placed before the motor of the pendulum, a safety device is, nevertheless, necessary, the duty of which is to stop the turbine as soon as the voltage across the leads to the motor fails. This may also happen if a short circuit occurs on the generator itself, so that the safety device must be designed to intervene in this case, as well. This safety device consists mainly of a lift magnet which, when it falls, moves the turbine regulating valve to the "close" position of the guide blades. The layout is generally such that the lift magnet is connected up to an auxiliary source of current. This circuit is broken through the agency of a minimum voltage relay connected up to the circuit of the pendulum motor and which acts as soon as the voltage has dropped to a value at which the pendulum motor no longer runs properly.

The Aarau Municipal Electricity Works (Switzerland), which was being made over, purchased a pendulum drive of this type, lately, from Brown, Boveri & Co., Ltd. In the plant in question, the safety device is arranged without the agency of an auxiliary source of current and according to the diagram of connections shown in Fig. 1.

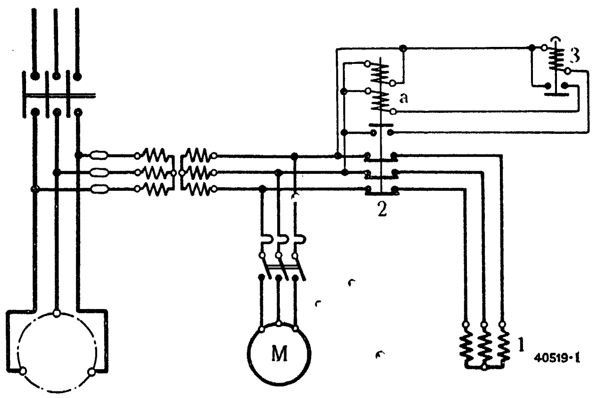

Fig. 1. — Electric drive of a governor pendulum with supply from the generator leads, with lift magnet as safety device.

At starting up, the lift magnet 1 is cut out by the minimum-voltage relay 2, the maximum-voltage relay 3 being in circuit. The latter is arranged so that it already acts under low voltage and energizes a special starting winding placed on the minimum voltage relay, through the agency of which the latter is activated and the lift magnet energized. The arrangement is such that a certain time lag is introduced, so that the lift magnet is only connected and the regulating process of the turbine set free after the pendulum motor has been started. At the switching-in of the minimum-voltage relay, a special contact causes the maximum-voltage relay to be cut out, as it is only required for the starting process. The minimum voltage relay is set for the lowest service voltage admissible for the pendulum motor. If the voltage drops below this value, the armature of the relay drops and breaks the current supply to the lift magnet. The fall of the latter sets the regulating valve to the no-load "close" position of the turbine guide blades. The failure or exceptional drop of the voltage

may be due to an external cause, as, for example, the failure of the generator voltage. If the voltage comes back, the lift magnet is raised and the former service condition is re-established. The time lag for the reclosing of the lift magnet circuit is important, here, as otherwise when the current to the pendulum motor comes back, the turbine gate valve will be opened wide by the lift magnet and the turbine will run away; this because up till the moment the pendulum attains full speed, it regulates to "open" the turbine guide blades.

Brown Boveri has delivered several pendulum drives similar to this one, with which, however, the safety device described was omitted, as reliable devices, which worked without a lift magnet, had been provided for. In order that the speed of the pendulum motor should be as nearly synchronous as possible, the armature of the said motor is designed with salient poles, unwound, but having a damper winding.

In sets for big outputs, where the price of the pendulum drive as compared to that of the turbine is insignificant, Brown Boveri considers it best to use a separate auxiliary generator, the only duty of which is to supply the pendulum motor. Both with horizontal and vertical shaft main generators, this auxiliary generator can be built on to the exciter, so that it always runs at the same speed as the main turbine-driven generator. This layout was used on the two 18,500-kVA generators put into the Lungern-Lake Power Station of the Zentralschweizerische Kraftwerke, Lucerne (Fig. 2).

The auxiliary generator G is a three-phase alternator with auto-excitation, 1 is the field winding and 2 a field rheostat which can be regulated. The turbine manufacturers demand that the pendulum motor should begin to revolve when the main set has reached 60 % of its rated speed. In order to fulfil this condition, under all circumstances, a battery is used to give separate excitation at starting. The automatic change-over switch 3 cuts out the separate excitation and closes the auto-excitation circuit, as soon as auto-excitation is powerful enough. 4 is an ordinary cut-out switch and 5 a series resistance. The latter is only necessary when the voltage of the source of separate excitation current is not the same as that of the D. C. current of the auxiliary generator. It has been found at starting up and, chiefly, when service tests have been successively repeated, that the pendulum motor begins to revolve at 70 % of the rated speed of the main set, when there is no separate excitation used and already reaches full speed at 75 % of the said rated speed. If the field rheostat 2 is short-circuited, the pendulum motor already starts up at 60 % of the rated speed of the main set and reaches full speed at 65 % of the rated speed. Service experience has fully proved that these starting conditions are amply sufficient, so that separate excitation can be done away with. The layout can, therefore, be further simplified when it is sufficient that the pendulum motor should start at 60 % of the rated speed of the main set, as is shown in the diagram of connections given in Fig. 3.

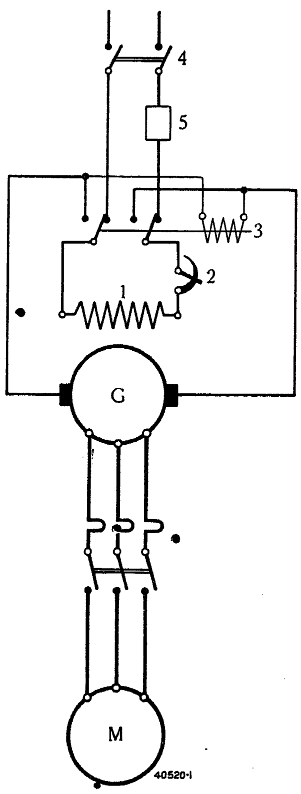

Fig. 2. — Electric drive of a governor pendulum with auxiliary auto-excited generator and separate excitation at starting.

As, at starting up, the field rheostat must be short-circuited, in order that sufficient excitation be available even at a low speed, an automatic switch 3 is provided, which shunts the field rheostat, at starting, and puts it into circuit again when the service excitation has been attained. In this way the field rheostat can be permanently left in its proper service setting.

A switch 4 with thermal release or fuses is also inserted between the auxiliary generator and the pendulum motor, so as to have a protection, here, as well against excess currents. When, however, this switch trips or when the fuses blow out, a quick-closing device, such as has been described above, or else a similar safety device should be activated.

Fig. 4 shows, as example, a turbine governor with electric drive in the Lungern-Lake Power Station. The gear-type oil pump with motor drive is seen mounted on the oil reservoir, which is designed as a base plate of the governor, and, above, the pendulum motor is shown, designed as a flange motor.

In cases where rapid starting of the pendulum motor is insisted upon, it is best to excite the auxiliary generator from a separate source, not only at starting but contin-

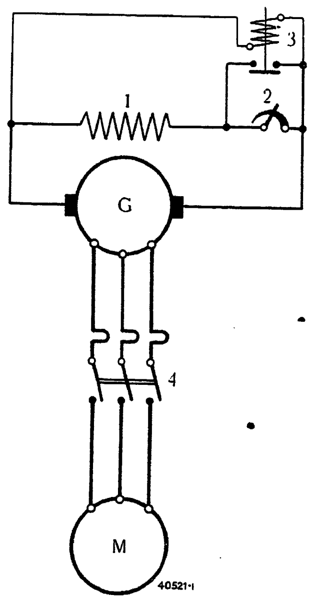

Fig. 3. — Electric drive of a governor pendulum with auxiliary auto-excited generator.

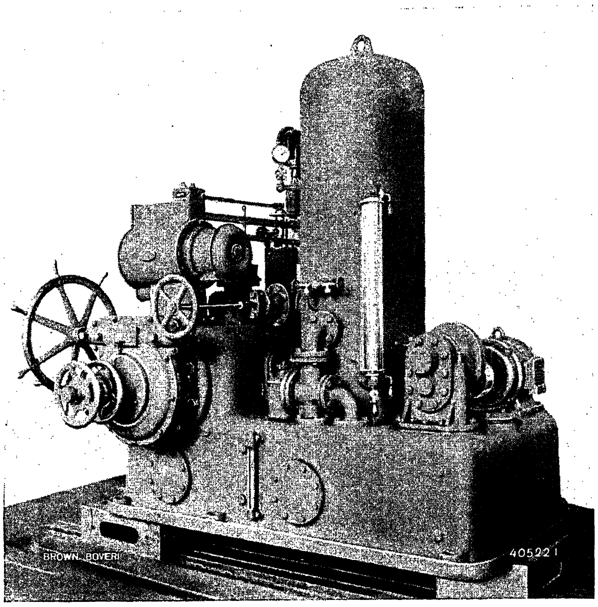

Fig. 4. — Turbine governor with electric drive of the pendulum and oil pump.

uously, as well. The Etzel Power Plant (Switzerland) is equipped in this way.

In the case of big slow-speed generators with which an auxiliary exciter is required for the purpose of automatic voltage regulation, it is possible to build this machine so that it delivers D. C. from the commutator and A. C. from slip rings for the supply of the pendulum motor. The only condition requisite is that the voltage should be constant on the D. C. side, that is to say that the machine be flat-compounded. Of course, an auxiliary generator of this kind cannot always be built for the same frequency as the main generator, but this is of no consequence as the frequency of the auxiliary generator also varies proportionately to the speed.

Wherever electric pendulum drive is desired, the pendulum motor as well as the generator or transformer necessary to supply it and the apparatus belonging thereto should be designed together; this is the only way of taking into full account the variety of conditions to be satisfied and thus of choosing the most advantageous solution for this case under consideration.

(MS 869) *G. Fisler. (Mo.)*

NOTES.

The scavenging blower sets on the motor ship "Prince Baudouin."

Decimal index 621.635.5 : 629.123.231.

THE Belgian motor ship "Prince Baudouin" was put on to the Ostend-Dover Channel service, about the middle of August 1934, and has given universal satisfaction (Fig. 1). This vessel, built in the Hoboken yards of S. A. John Cockerill, Seraing, is interesting not only as being the first motor ship to be put into passenger service on the Channel but also, because its highest speed of 25 1/4 knots makes it the world's fastest motor ship.

The special conditions which characterize this vessel obliged the engine makers to develop designs, which, on the one hand, were extremely light and took up little space and, on the other hand, were absolutely reliable in service. This demanded carefully selected constructional material for fundamental parts, metals of the highest grade for those parts subjected to high mechanical stressing and, finally, light metals for parts which are not highly stressed such as housings, shields, etc.; it also made necessary a thoroughly studied construction of the auxiliaries of the engines, to meet the special requirements of the case.

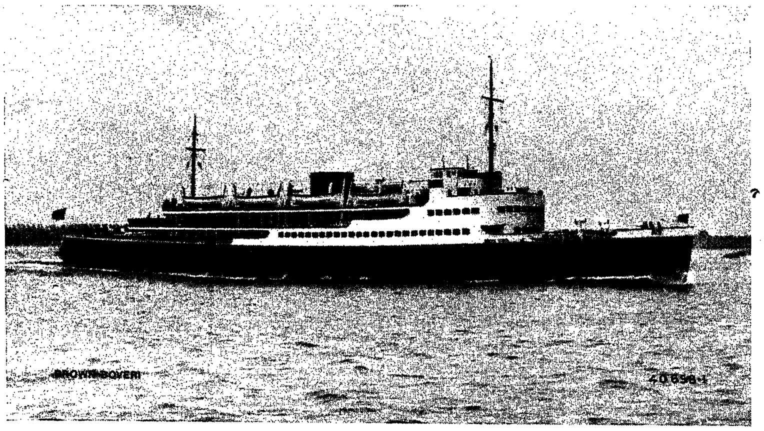

Fig. 1. — Motor ship "Prince Baudouin" driven by two-stroke Diesel engines of Cockerill-Sulzer design; each of 8500 eff. H. P.
The scavenging air is delivered by three electrically driven turbo-blowers of Brown Boveri design.

Among the latter, the Brown Boveri scavenging blowers described here are worthy of note.

There are three sets of these scavenging blowers, one of which acts as a spare, each being designed for 840 m^3/min volume of indrawn air at a pressure ratio of 1 to 1·23 kg/cm^2. The sets supply two 12-cylinder, two-stroke Diesel engines of Cockerill-Sulzer design, each of a maximum output of 8500 effective H. P. at 268 r. p. m. The rated speed of the blower sets is 2320 r. p. m. which can be varied in the range of +5 —15 % of this figure.

Each of the scavenging blower sets is composed of a two-stage centrifugal blower driven by a D. C. motor (Fig. 2). The motor and blower have a common shaft and form a single unit with two end bearings. The

fundamental design is shown in Fig. 14, page 74 of the Brown Boveri Review of the year 1924, No. 4. All bearings are of the roller type. The set has a single, closed-circuit forced-oil lubricating system, the oil being kept in circulation by a gear pump.

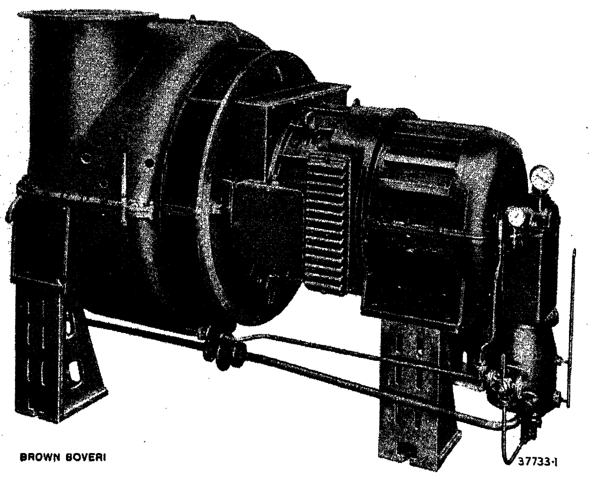

Fig. 2. — Two-stage Brown Boveri scavenging turbo-blowers of light design for the motor-ship "Prince Baudouin", each built for 840 m³/min of air at intake 2300 mm scavenging pressure, 2320 r. p. m.

All parts of housing are built of light metal impervious to sea water.

A bedplate has been done away with, for the sake of lightness. The lower halves of the blower and motor housings are rigidly bolted together and the set rests on the framework of the ship through supporting feet placed at the sides and ends of the motor and blower. Further, the blower and motor housings are made of a light metal impervious to the effects of sea water, the magnetic core of the motor stator being composed of a ring of forged iron lodged in the said housing. Each motor has a continuous rating of 450 kW at 220V. The cooling of the motors is by fresh air tapped directly from the intake of the blower.

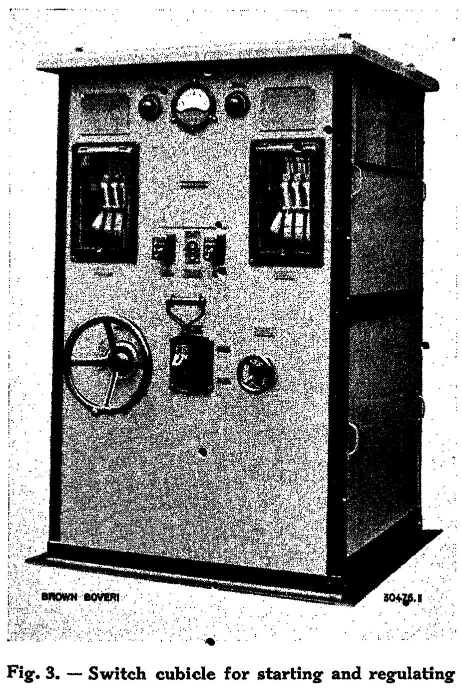

Fig. 3. — Switch cubicle for starting and regulating scavenging turbo-blowers.

There is a switch cubicle, similar to that shown in Fig. 3, for switching in, starting and regulating the speed of the set. This cubicle contains all the safety devices and interlocks which many years of experience have shown to be necessary, or useful.

Fig. 4 shows how the blowers are placed in the ship. As usual, in cases of this kind, the blower part is placed in a sound-proof air suction chamber so that the noise made by the air intake is imperceptible in other parts of the ship. This noise is reduced to a minimum, in any case, thanks to special constructive measures characteristic of Brown Boveri blowers. A complete elimination of noise at the intake cannot be attained, however, with turbo-blowers, especially when special restrictions are imposed on the designer, as regards weight and space, as is the case here.

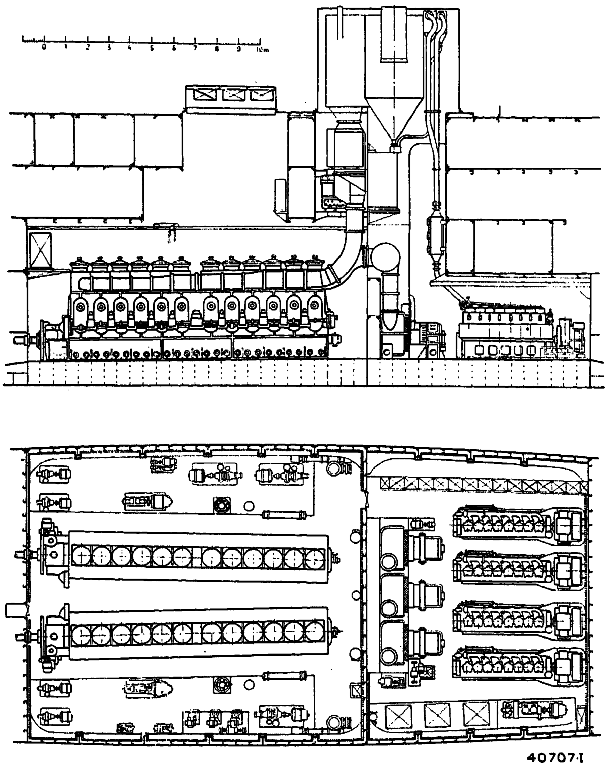

Fig. 4. — Layout of the Diesel engines and scavenging blowers on the motor ship "Prince Baudouin".

The experience of many years which Brown Boveri enjoy in the field of scavenging blowers for motor ships of which the firm has delivered over 250, mostly for first class passenger vessels, has proved that, granted proper installation of the blower plant on board, all troublesome noise is done away with. As Fig. 4 shows, not only the scavenging blowers, but also the Diesel engines of the "Prince Baudouin" are mounted so as to be sound-proof as regards other parts of the vessel, the whole engine room being lined with sound-absorbing materials.

(MS 894) *Th. Geiger. (Mo.)*

Storage-battery motor coaches for Italian local lines.

Decimal index 621. 335. 4. 033. 46 (45).

THE disadvantages inherent to steam-operated railways, such as low commercial speeds, high maintenance costs,

smoke and soot, inadaptability to handle overloads, are especially evident on local lines which still use steam locomotives. The competition of motor transport, to-day, has spurred the managements of local railways to serious efforts to improve their lines, both as regards economy and commercial efficiency. There are several operating methods available which may, in certain cases, be superior to steam for local lines, such as service with electric locomotives, Diesel-electric and purely Diesel motor coaches or rail motor buses. Among these alternative systems, electric storage-battery motor coaches have won a position of some prominence as is shown by the fact that three local Italian railways have changed over, within recent years, to this system of drive and with excellent results. Tecnomasio Italiano Brown Boveri delivered the electrical equipment of the motor coaches required for the said railways.

The chief data concerning the railway systems in question is given herewith:—

Railway Co.:—	S.A. Compagnia Generale delle Tranvie Piemontesi Saluzzo	S.A. Tranvia Monza-Trezzo Bergamo	S.A. Tranvie Vicentine Vicenza
Line section:—	Turin-Saluzzo-Cuneo-Boves, Cuneo-Dronero	Monza-Trezzo-Bergamo	Bassano-Vicenza-Montagnana
Gauge	1100 mm	1445 mm	1445 mm
Total length	110·6 km	40·1 km	79 km
Steepest gradient	35·4 ‰	32·5 ‰	25 ‰
Number of motor coaches	6	3	1
Dead weight	29·7 t	28·5 t	34·0 t
Max. train weight	60 t	46 t	48 t
Max. speed	50 km/h	45 km/h	75 km/h
Hour rating of motors	164 H. P.	156 H. P.	196 H. P.

The motor coaches are of the four-axle type with seating accommodation for 70—100 passengers. They are about 14 metres long. Fig. 1 shows a motor-coach of the Piemontesi Saluzzo Tramways, an interesting feature of which is the way the battery is suspended under the floor of the coach; the design being such that the separate battery cells can be interchanged without any difficulty, one man sufficing for the job.

The electric equipment is extremely simple, being composed of the usual parts used in tramway design. Speed regulation is by series-parallel connection of the four motors, with the insertion of starting resistances. Braking can be by compressed air or electrical (short-circuit braking of the motors).

The batteries are of the lead grid plate type, of 210—285 kWh capacity, designed for a five-hour discharge; they weigh about 8·8—11·4 t, corresponding to about 40 kg/kWh. Assuming an average train weight of 35 t the travel range of the coaches is about 180—245 km allowing for 10 kg/t rolling resistance and for travelling on the level without a stop.

The mechanical part of the dead weight of a coach accounts for about 52 % of the dead weight, the electrical equipment accounting for 15 % and the battery for 33 %.

Service results obtained, for example, with the six motor-coaches of the Piemontesi Saluzzo Tramways are worthy of note. As reported by the manager of the railway, Doctor Lo Balbo[1], service with storage-battery motor coaches resulted in a saving in service charges (in train-kilometres), even in the first year, of 35 %, as compared to steam operation. Therefore, the change over to electric drive was fully justified. Electric drive has, further, the welcome qualities of cleanliness, of being odourless, of allowing of more comfort in the design of the coaches, of a higher commercial speed and, finally, of simplicity in operation; all qualities which helped to increase the traffic handled despite the present economic crisis.

The average power consumption of these motor-coaches is about 30 Wh/tkm which corresponds to a commercial speed of 23—30 km/h.

As the batteries are charged during the night, the electric power required for this purpose can be obtained very cheaply (in Saluzzo, for example, at 0·085 Lire per kWh). The maintainance of the storage batteries is in the hands of the manufacturer, who charges a fixed rate for this.

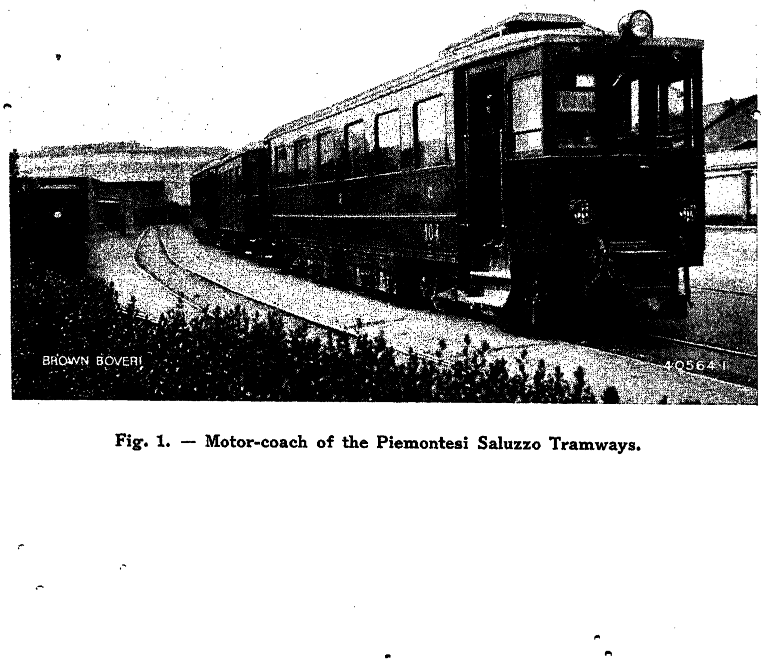

Fig. 1. — Motor-coach of the Piemontesi Saluzzo Tramways.

The favourable service results attained with the motor-coaches described here show that, in certain cases, the storage-battery motor-coach can be a successful competitor of the steam locomotive. It would seem that under propitious conditions, this system is a very suitable solution for local-line operation. The tests carried out in the early days of electro-technology, with the object of introducing storage batteries to railway traction service, were not successful owing to the short life of the batteries available of that time. Thanks to the progress which has been made, since then, in the manufacture of batteries for traction purposes, the storage-battery motor-coach is beginning to take its place as a practical proposition, alongside non-electrical and electrically driven coaches of all kinds. *(MS 879)* *O. Gysin. (Mo.)*

[1] Traction Electrique, IInd Annual, Number 6, IIIrd Annual, Number 4.

23 express locomotives Type 2 D_o 2 with Brown Boveri individual axle drive, for the French State Railways.

Decimal index 621.335.2 (44).

THE electrification of the Paris-Le Mans line, belonging to the French State Railway system, formed part of the programme of public work drawn up by the French Government to relieve unemployment. Just before the end of 1934, the said railway placed an order for 23 electric locomotives for express service, with Brown Boveri's French concessionaries, the Compagnie Electro-Mecanique, Paris, as general contractors. The one-hour rating of each locomotive is 4000 H. P. and they are supplied with D. C. at 1500 V. The maximum speed is 140 km/h. They are of Type 2 D_o 2 and their features are identical to those of the machines of same type and design delivered to the Paris-Orléans Railway, Series E 503-E 537 (see The Brown Boveri Review, numbers 8 and 9, year 1927, number 6, year 1933 and number 5, year 1934). The locomotives of the French State Railways are not equipped for power recuperation, however, and their weight per unit will be about 127·5 t as against 142 t for the Paris-Orléans locomotives.

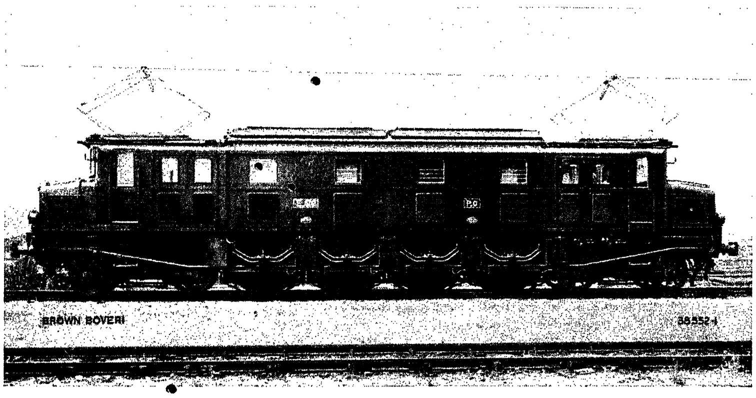

Fig. 1. — Express locomotive Type 2 D_o 2, Series E 503-E 527 (delivery 1933/34). D. C. 1500 V, 4000 H. P., maximum speed 130 (140 km/h).

The structural part of these locomotives will be built by the Compagnie Fives-Lille.

Like those of the Paris-Orléans Railway, all these locomotives are equipped with Brown Boveri individual axle drive in its original design, namely with the drive outside the frame of the locomotive proper and having automatic gravity and pump lubrication.

The placing of this big order is certainly due to the highly satisfactory results attained with the 27 express locomotives Type 2 D_o 2 running on the electrified sections of the Paris-Orléans Railway. The extraordinarily good running qualities of the latter machines, their reliability and low upkeep charges have never been improved on by any express locomotives delivered up till to-day by competing firms. There are 10 additional locomotives, ordered by the Paris-Orléans Railway at the end of 1933, which are of the same design as the former ones, at present being built. Delivery will begin in the spring of this year.

It is interesting to recall here, while on the subject of these machines, that at the beginning of November 1933, one of them No. E 504, drew the South Express and covered the 100 km of the Juvisy—Les Aubrais line section in 40 minutes drawing a train of 475 t. This corresponds to an average speed of 150 km/h, one never yet exceeded with trains of this weight. The maximum speed attained was 158 km/h.

The oldest locomotive of this series, No. E 501, has already covered 1·4 millions of kilometres since it was delivered in 1925. This corresponds to 35 times the circumference of the globe and has been accomplished without it having been necessary to replace, on account of wear in service, any vital organ either of the mechanical equipment—including the drives—or of the electrical equipment. This locomotive has still got its original gear wheels, motor bearings and commutators, which have only been smoothed once or twice.

The stability of these locomotives when travelling on the straight or on curves is unsurpassed and this up to the highest speeds mentioned here. This is, in great part, due to the special construction of the bogies of these machines.

There will be, shortly, not less than 60 express locomotives of this design with Brown Boveri individual axle drive in service on French railways alone.

(MS 891) *E. Schrœder. (Mo.)*

Hydro-electric development in Southern India.

Decimal index 621.311.21 (54).

THE government of Travancore has started work on an extensive scheme of electrification extending over the northern part of the State. A generating station is being built at Pallivasal in the High Range District. To this purpose, the Munnar river is to be dammed up to 1325 m above sea level, the water being conveyed to the forebay, from which the penstocks take off, through a tunnel about 3 kilometres long. The power house situated at 828 m above sea level, will have a layout for six horizontal-shaft generating units with step-up transformers, three 66,000-V feeders for transmitting power to the plains, and two 11,000-V feeders leading to the High Range tea estates.

The first stage of development covers three 4500-kW generating units, two 66,000-V and two 11,000-V feeders. The second stage will necessitate building a dam about 25 kilometres up stream, across a valley. The water thus stored will be the surplus supply due to the rainy season, which occurs yearly. This will raise the total power available to 40,000 kW.

The present equipment includes:—

2 pelton water wheels each designed for $1 \cdot 13\ m^3$/sec of water under a head of 570 m and each delivering a rated output of 6000 H.P.

2 three-phase, 50 cycle alternators, each for 5000 kVA rated output at 750 r. p. m., 10,000 to 12,100 V terminal voltage, power factor $= 0 \cdot 90$.

2 three-phase transformers with three windings 5000/1500/3500 kVA, 11,000/11,000/66,000 V.

1 outdoor switching station with remote-controlled oil circuit breakers on the high-tension side of the transformers and for the 66,000-V feeders.

1 control room, laid out for the final installation with indicating diagram and indicating relays showing the position of all isolating switches and oil circuit breakers.

1 complete station auxiliary plant.

The horizontal-shaft generating units are of the two-bearing type with the turbine runner mounted overhung on the shaft. For the alternator a special design is necessary in order to incorporate the very high flywheel effect of 16,000 kgm^2, to keep the momentary change in speed, when a heavy load is thrown on or off, within close limits. Particular attention was paid to the charging load of the extensive 66-kV transmission system, and the alternators are each designed for delivering a wattless load of 4000 kVA at zero leading power factor, at 10,000 V with sufficient positive excitation to be applied to its field windings to render it stable when charging the transmission system alone or in parallel with similar machines. Due to the wide range of excitation, viz. 10,000 V terminal pressure at 4000 kVA, zero leading power factor up to 12,100 V at 5000 kVA, $0 \cdot 9$ lagging power factor, the exciter is separately excited from an auxiliary or pilot exciter mounted overhung on the main machine.

Each alternator will be coupled to a three-winding transformer of equal output. One high voltage winding designed for 3500 kVA will raise the voltage to 66,000 V, the other of 1500 kVA, at a voltage of 1/1, will supply the 11,000-V local distribution system.

The transformers are of the oil-immersed, self-cooled, out-door pattern with neutral brought out on both secondary windings, for solid earthing. The primary winding will be connected in delta; the two secondary windings, in star connection, will each be provided with tappings for 2 ½ % and 5 % of the rated pressure.

The transformers from a complete unit with the appropriate alternators and oil circuit breakers are provided only on the secondary windings. To render the station more flexible, a transfer bus-bar will be installed to allow any transformer to be connected up to any alternator; this is useful when the station is being overhauled, or if there is trouble either on the generator or transformer side.

The 66,000-V switching station will be of the outdoor floor-mounted type and laid out on the double bus-bar system. Such an arrangement is very reliable in service and in addition allows for easy supervision and maintenance.

The oil circuit breakers, with all three phases, contained in a single round-shaped tank of mild steel, will have motor control electrically operated from the control room. Heaters built into the tanks will keep the top layer of oil at a temperature above that of the surrounding air to prevent condensation. The isolating switches will be of the three-pole type designed for rod control they will be fitted with auxiliary switches for signalling and interlocked arrangements, where necessary.

Special attention has been paid to a satisfactory control-room layout allowing easy supervision.

A mimic board is included to indicate to the attendant the momentary position of the 11,000-V transfer busbar system and 66,000-V outdoor switching station.

The 11,000-V distribution switchgear, which includes a single bus-bar system, will be of the iron-clad type completely closed, thus allowing of it being lodged in the control room itself. The oil circuit breakers, current transformers and heavy-current plug terminals are mounted in trucks, the front panels of which carry the built-in measuring instruments and controls.

When the trucks are wheeled out, as happens for inspection, double steel doors automatically shut off the interior of the cell in question and thus not only provide for safety, but in addition restore continuity of the 11,000-V board.

The 11,000-V transfer bus-bar system is located in concrete cubicles underneath the control room. These are provided with sheet steel doors in front.

An interlocking arrangement prevents the isolating switches being operated when the corresponding transformer high-tension isolators are closed.

With the auxiliary plant will be installed two 125-kVA regulating transformers which automatically keep the secondary pressure constant at 400/230 V irrespective of fluctuations in the primary voltage, which may vary from 10,000 to 12,100 V. The auxiliaries further include a 110-V battery with charging equipment, an oil-filtration plant and a portable oil-testing equipment.

The contract for the complete electrical equipment for the power house, including all power and control cables, has been placed with Messrs. Brown, Boveri & Co., Ltd., Baden, Switzerland. Messrs. Escher Wyss Engineering Works, Zurich, will supply the water wheels.

The station is required to be erected, commissioned and ready for commercial use on or before the 1st May, 1936.

(MS 883) *H. Oswald.*

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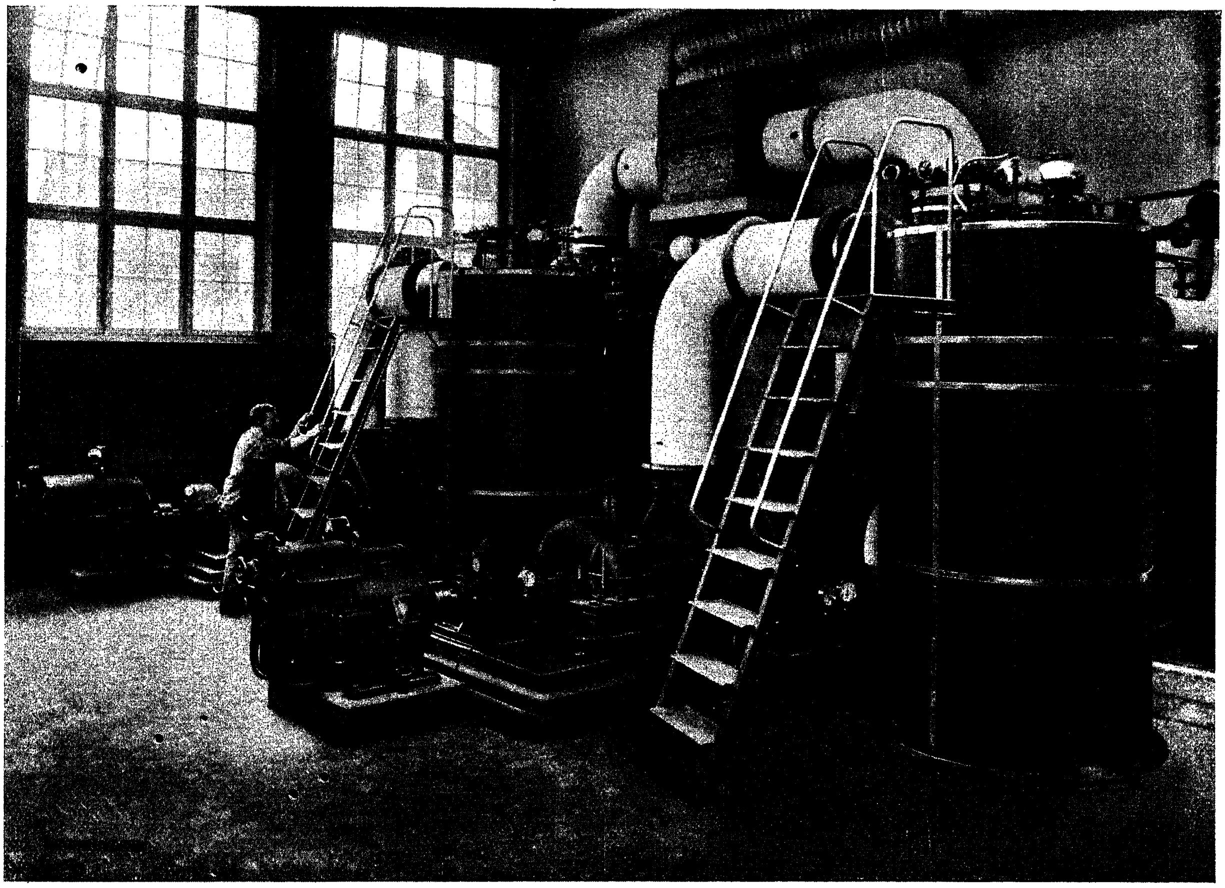
VOL. XXII MAY, 1935 No. 5

THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



TWO VELOX HEAT GENERATORS IN THE HEATING PLANT OF THE CANTONAL HOSPITAL, AARAU (SWITZERLAND).
These two heat generators are used to cover peak loads and as spares in a heat-distribution system which is supplied by cheap waste power from the municipal power station.

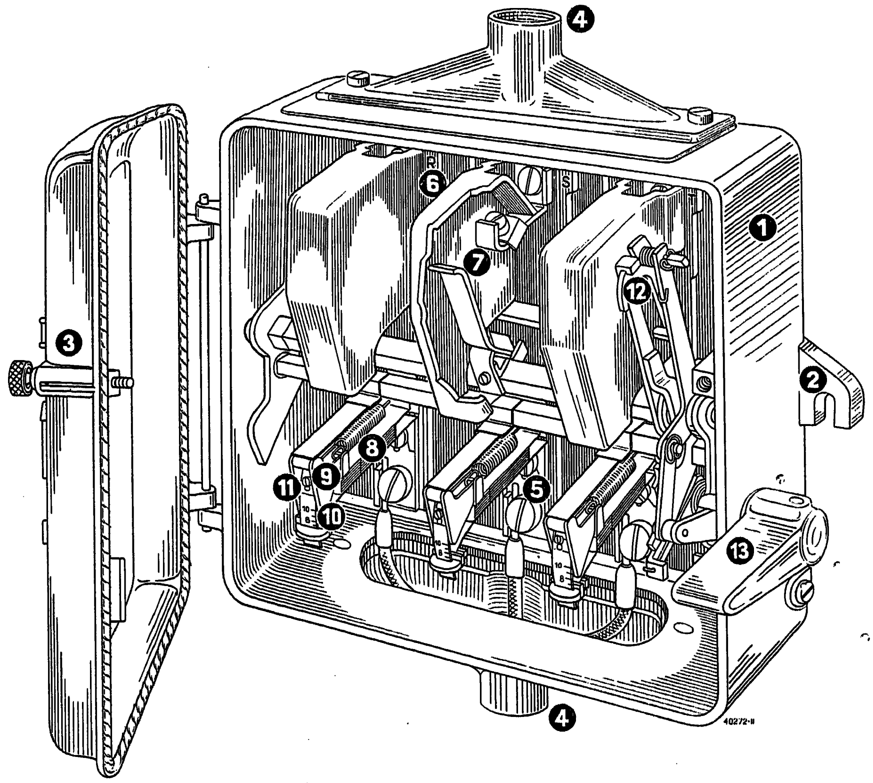
CONTENTS:

Printed in Switzerland

THE BROWN BOVERI THREE-POLE SWITCHBOX TYPE N 2

with thermal release, is the best imaginable type of switch protection for a motor

Its range of utilization extends to 25 amps. rated current at 380 volts and to 22 amps. rated current at 500 volts. It also completely protects small motors for as low-rated currents as 0·5 amps.



Some of the many advantages of this new switchbox are given herewith:—

1. Dust and splash-proof housing made of light metal (weight only 2·35 kg). Compact design, takes up little space.
2. Easy to mount by means of hooks. Generally mounted vertically but can be placed flat or inclined, as required.
3. Cover and switch interlocked. Lead seal can be added to prevent unauthorized manipulations.
4. Leads can be brought in as desired from above or below, or the switchbox can be mounted in line with the supply cable.

   Connecting branches designed for the most varied applications. (Steel conduit, cable, mounting in a switchboard.)
5. Specially designed terminals allowing of connecting up leads, simply and reliably, without having to form an eye.
6. Double terminals for through neutral wire.
7. Durable good contacts due to massive silver plating on the contact pieces, which are also easy to replace.
8. Brown Boveri thermal releases which years of experience have shown to be thoroughly reliable under the severest service conditions.
9. Combination of the thermal release with a trigger spring. This makes the release quite insensitive to small inaccuracies in fitting, for instance when the releases are changed against others of another current strength.
10. Combination of thermal release with its setting device in such a manner that immediate reading of the setting is secured. It renders basic setting, which is often troublesome, unnecessary.
11. Setting to the rated current of the motor to be protected, that is to say in accordance with the rating-plate indications on the motor instead of according to some excess-current value which had first to be calculated.
12. Direct tripping by trigger action on the switch. After tripping, automatic return of the release to previous position, therefore, immediate readiness for taking up service again.
13. Insulated control handle. Free clutch securing tripping even if the handle is held in closed position.

Ample space, good supervision, great accessibility, no special tools required.

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXII | MAY, 1935 | No. 5

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THE PUMPING PLANT SUPPLYING THE TOWN OF LAUSANNE WITH DRINKING WATER FROM THE LAKE OF GENEVA.

Decimal index 628.122 (494).

BEFORE the pumping station at Lutry was built, the town of Lausanne was supplied with drinking water from springs in three different regions, namely:—

From the Jorat region, with an average summer flow of . . . . 4200 l/min

From the Pays-d'en-Haut region, with an average summer flow of . . . . . 9700 l/min

From the Pont de Pierre region, with an average summer flow of . . . . . 3500 l/min

Thus, the total average summer supply from these combined sources is 17,400 l/min, which falls to 13,000 l/min in winter. The water from these sources supplies, by gravity, 10 reservoirs holding 24,300 m³ in all.

In the 1921—1928 period, the available supply in July and August was about 16,000 l/min and in the winters of these years, during periods of hard frost, the supply shrank to about 10,500 l/min. On the other hand, the population supplied by the Service des Eaux rose, between 1910 and 1930, from 66,000 to 84,000 and the water consumption on a hot summer day rose from 24,000 to 36,000 m³. As there were no more springs which could be tapped available, it became urgent to build the pumping plant to take water from the lake, plans for which had already been drawn up.

On the 12th of May, 1931, the Conseil Communal (District Council) authorized the Municipality to build the said pumping station, located on the east side of the township of Lutry at 378 m altitude. This location was considered to be the most advantageous, the bottom of the lake being hard and steeply inclined here. The water is tapped at a distance of 380 m from the bank of the lake at a depth of 38 m below the surface and 14 m above the bottom. The pipe line submerged in the lake is built of steel sheeting, has a diameter of 470 mm and is 460 m long, up to the suction shaft in the pumping station. It allows of a supply of 18,000 l/min to be carried to the suction shaft, or sump, of the pumping station by simple siphon action alone.

The Service des Eaux, further, built two new reservoirs:— the Montétan reservoir, holding 3400 m³ and located at 484 m altitude, where the pipe line under pressure ends, and the la Châblière reservoir, of the same capacity but at 554 m altitude. These reservoirs are located on the west side of the town.

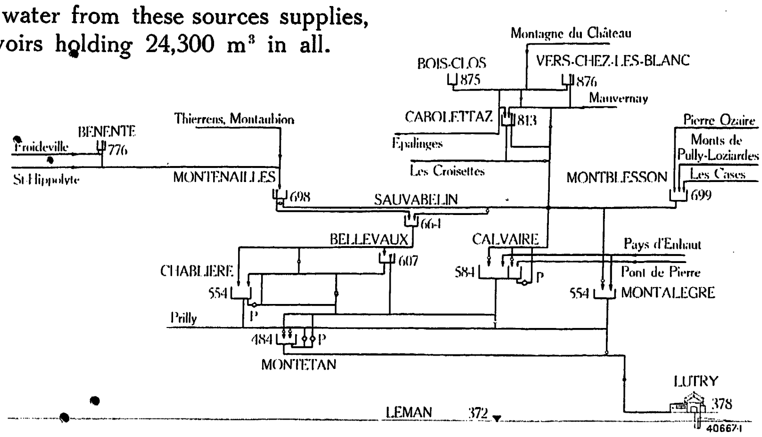

Fig. 1. — Services Industriels, Service des Eaux, Lausanne. Diagram of drinking-water distributing system.

Fig. 1 shows the drinking water supply system of the town of Lausanne diagrammatically. It is seen that the lake water can be pumped up to the Montblesson reservoir at 699 m and to the Bellevaux reservoir at 607 m, which allows of supplying nearly the whole town with water. It must be added, here, that the pressure pipe from Lutry also feeds the Lutry, Paudex and Pully districts as well as the south-east quarter of Lausanne.

1. *Lutry pumping station.* — The 50,000 V-transmission line between the Bois-Noir power station at St. Maurice and the town of Lausanne, supplies the power required to drive this pumping station. The said power is tapped in the Bois-de-la-Chaux switching station (Fig. 2).

Switching station — The switchgear of this station comprises two three-pole isolating switches mounted on the main line, before and after the branch point, so that it is possible to cut the main line into two sections; in cases of trouble occurring on either section and this allows of supplying the necessary pumping power either from the St. Maurice end or from the Lausanne end. The branch lead passes through a three-

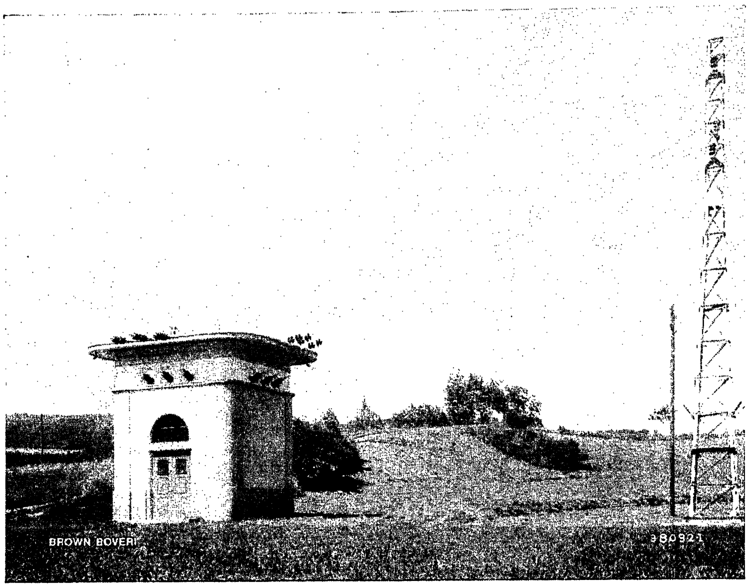

Fig. 2. — Bois-de-la-Chaux switching station; outside view.

pole isolating switch and a three-pole oil circuit breaker with a rupturing capacity of 450,000 kVA, having two maximum current series relays. The breaker is operated by power accumulated in a spring, the latter being wound up by motor. The breaker can be operated by means of the telephone line from the Pierre-de-Plan station in Lausanne or else, by hand, in the switching station itself.

Pumping station (Fig. 4). — A single building contains the whole station equipment, namely:— the transformer station, the machinery hall, the filtering and chlorinating plants, the repair shops and attendant's dwelling.

The transformer station contains two three-phase oil-immersed transformers each of 800 kVA output, 50,000/500 V, 50 cycles. The two 50,000-V circuit breakers are lodged each in its own cell closes off by a roll-type door which can open automatically under excess pressure so as to let gases, which may be generated in the cells, escape to the outer air, thus eliminating all danger of an explosion. The 500-V apparatus is located in a certain number of cells over which run the bus-bars from the secondary terminals of the transformers. Two three-pole isolating switches allow of connecting up either transformer or both together to the bus-bars in question.

All the main motors of the pumping station are remote-controlled, by push-buttons. The apparatus of each comprizes three heavy-current fuses, a three-pole contactor and two maximum-current relays of the thermal-tripping type (Fig. 5). Further, the two 250-kW motors and the 450-kW motor are each equipped with a three-phase, oil-immersed static condenser, in a cell, direct-connected to the supply cable of the motor These condensers are dimensioned to keep the p. f. at unity between full load and one quarter load of the motor. The lighting and auxiliary services can be switched over to a 50-kVA transformer, 500/220/125 V, or to the low-voltage supply of the town of Lutry, if the transformer station is dead.

The plant was built in two stages, first the two 250-kW sets with two auxiliary sets 26 kW of vertical-shaft type, seen in the background in Fig. 6, then, six months later, a third set, 450-kW, with auxiliary, vertical shaft 52 kW set, which are seen in the foreground of Fig. 6.

The water flowing into the suction shaft, or sump, by siphonage action is, first, passed through the filters by the auxiliary pumps. The first two auxiliary pump sets are each composed of a vertical-shaft three-phase centrifugal-starter motor of 26 kW, 1500 r. p. m. direct-coupled to a low-head centrifugal pump, delivering 6—7000 l/min

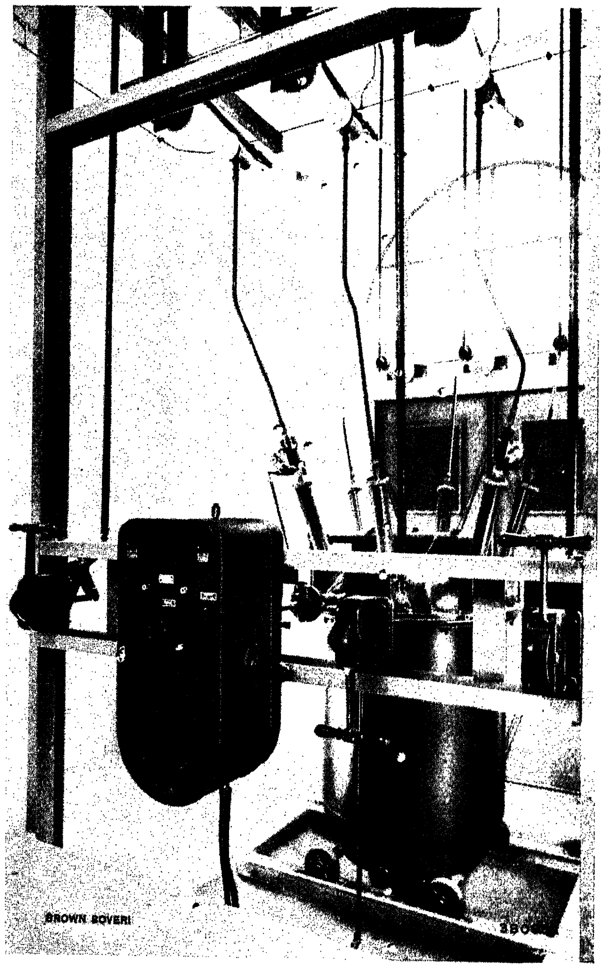

Fig. 3. — Bois-de-la-Chaux switching station; inside view.

against a total head of 13 m. The third set is equipped with a 52-kW motor at 1000 r. p. m. which drives a pump delivering 12—15,000 l/min, against a total head of 13 m. The water, having been filtered, is delivered to a pure-water reservoir of 900 m³ and drawn from here by the suction branches of the three main pumps which then pump

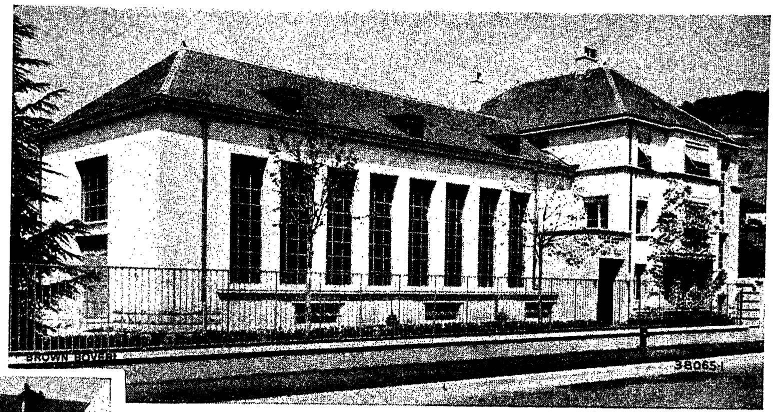

Fig. 4. — Lutry pumping station; outside view.

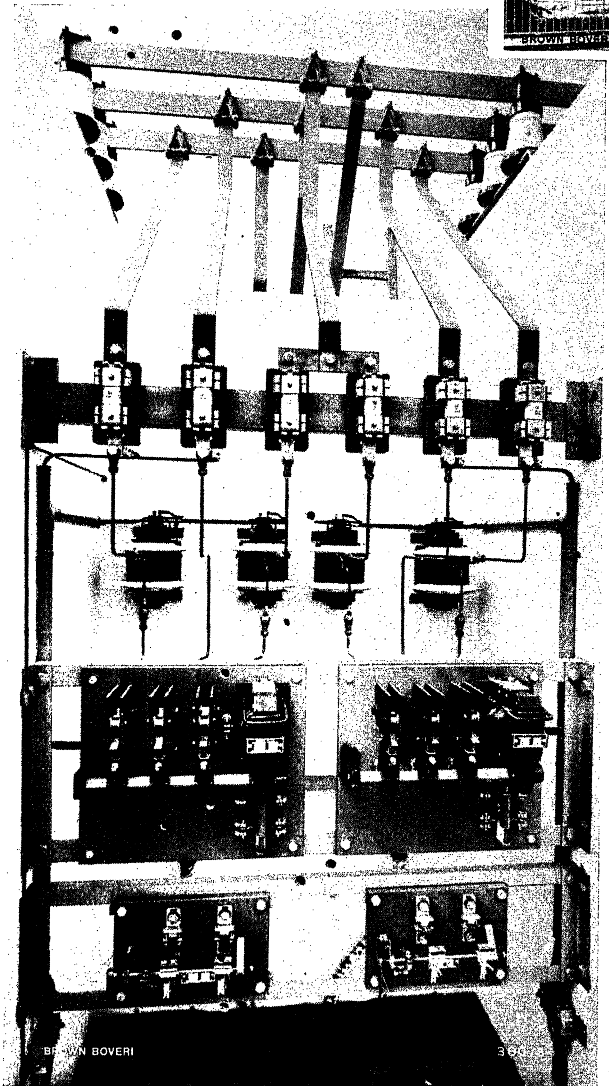

Fig. 5. — Lutry pumping station; switchgear cell for two motors.

it up through the steel-tube pressure pipe into the Montétan reservoir in Lausanne.

The two first main-pump sets are each composed of a three-phase induction motor with centrifugal starter of horizontal-shaft type, 250 kW, 1500 r. p. m. direct-coupled to a high-pressure centrifugal pump of 6—7000 l/min output against a total head of 145 m. The third set is driven by a horizontal-shaft, slip-ring motor, 450 kW, 1500 r. p. m., having its starter placed beside it. The starter is equipped with a servo-motor electrically connected to the three-pole contactor lodged in one of the cells of the transformer station. This allows of operating this motor as well by push-button. When the "Close" button is depressed, the contactor closes its current circuit, the servo-motor of the rotor starter is actuated and rotates the starter drum; the starting resistances are gradually short-circuited. Finally the brush-raising short-circuiting device is actuated after which the servo-motor comes to a stop the "working" position having been attained. If the "Open" push-button is depressed, the contactor opens and cuts off the current to the stator of the motor. When the next "Close" impulse is imparted, the servo-motor first brings the shaft of the starter back to the "Start" position, after which the stator contactor is actuated and then the starting operations are carried out as described. There are two sets of push-button switches for the control, one on a small wall panel and another on the starter itself. This motor can also be

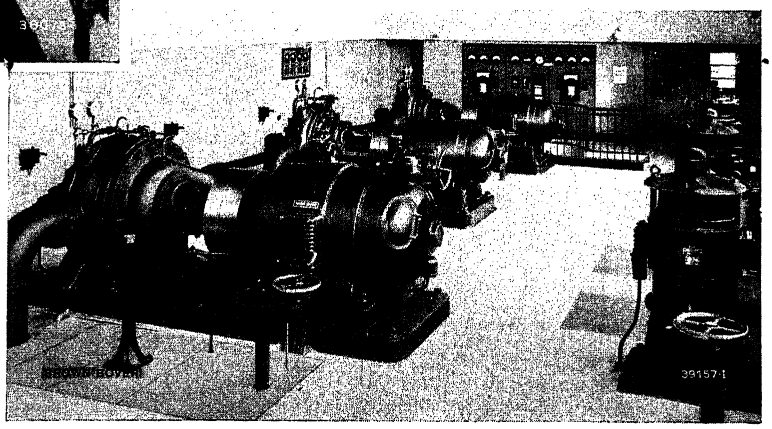

Fig. 6. — Lutry pumping station; machine hall.

operated directly by hand by using the handwheel on the starter shaft end. To do so, the coupling between servo-motor and starter drum must first be loosened. The starter is rotated, by means of the handwheel into the corresponding end position, to effect starting, and into the opposite end position to effect stopping. This results in the contactor of the motor being either switched in or out at the same time, automatically.

This third motor is coupled to a centrifugal pump delivering 12 to 15,000 l/min against a total head of 145 m. The couplings between motors and pumps are of the flexible flywheel type which prevents a too sudden stopping of the sets, with the object of avoiding a break in the column of water in the pressure pipe.

The control panel of the two 250-kW and two 26-kW vertical shaft motors is also seen in Fig. 6, countersunk in the left wall. This panel carries a set of push-buttons for each motor, for closing and opening, as well as an ammeter. The switchboard with three panels, at the back of the room, is reserved for various control apparatus and for the relays protecting the 800-kVA transformers. The wing panels each carry three ammeters and two maximum current relays for the 800-kVA transformers; one, also, carries a water-level indicator for the pure-water reservoir and the other a similar apparatus for the Montétan reservoir, where the pressure pipe ends. The central panel carries:—

1 static voltmeter for connecting to condenser on the 50,000-V side.
1 double-registering wattmeter (watt and wattless power),
1 kWh meter,
1 Venturi-type flow-meter,
1 voltmeter } on 500-V side.
1 p.f. meter }

The filters have a surface of 150 m² and are composed of quarz sand 1 m 50 thick deposited in six concrete basins. Their total capacity is about 15,000 l/min. The filtered water runs off through a system of small copper nozzles, of which there are about 2000 lodged in the bottom of each basin, and thus reaches the pure-water reservoir of 900 m³ capacity after passing through a system of valves controlled from the control desk of the filter room. This reservoir supplies the high-pressure pumps. By adding about 0·1 gr. of chlorine to 1000 litres of water the water is rendered bacteriologically pure, its taste not being affected by such a small amount of chlorine. This process is carried out on the suction branches of the high-head pumps. After a certain operating time, it becomes necessary to wash the quarz sand. To this end, the valves mentioned in conjunction with the pure-water reservoir are used to force air and water under pressure through the numerous copper nozzles in the floor of the basins. The air shakes up the sand and the water carries off the impurities it contains and is discharged into the lake. The compressed air is delivered by a Brown-Boveri blower rotating at 11,200 r.p.m. and delivering 30 and 37 m³ of air per hour against a total head of 5 and 3 m of water, respectively, at the discharge flange. This blower is driven through an oil-immersed reduction gear by a 45-kW induction motor at 3000 r.p.m. This set is mounted on a concrete pedestal separated from the floor by an insulating plate of special cork. The scavenging water is supplied by a motor-pump set composed of an induction motor with centrifugal starter 13 kW at 1500 r.p.m. direct-coupled to a centrifugal pump delivering 4500 l/min against 12 m total head. These two sets are also controlled by push-button switches on the control desk of the filter room.

The auxiliary service sets are placed in the pump room and are three in number:—

1 vacuum pump set for initiating siphonage action;

Fig. 7. — Montétan pumping station; outside view.

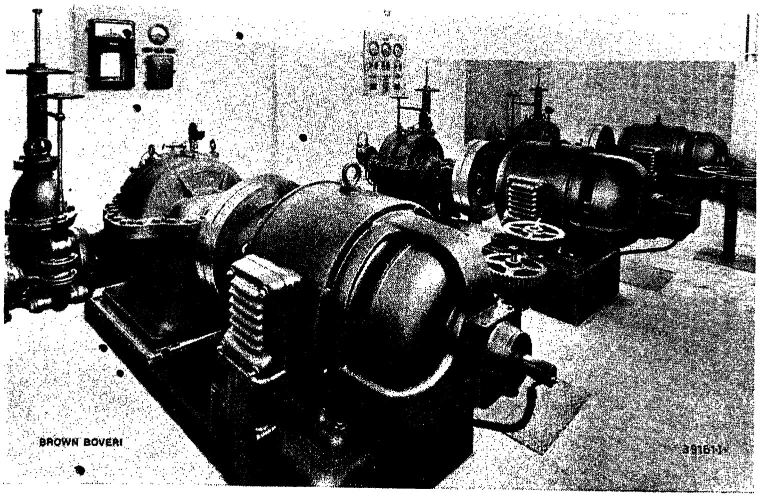

Fig. 8. — Montétan pumping station; machine hall.

1 compressor set for completing the volume of air of the air bell or air reservoir, which is branched on the pressure pipe. This bell prevents rupture of the water column in the said pipe, if the electric current is suddenly cut off;

1 motor 3 kW at 1500 r. p. m. operating the main sluice valve of the pressure pipe, through a gear.

These three motors are hand-controlled by switch-boxes equipped with thermal tripping devices.

2. *Montétan pumping station* (Fig. 7). — As was said at the beginning of this article, the Service des Eaux built two new reservoirs, one of which was Montétan situated at an altitude of 484 m and having a capacity of 3400 m^3; where the pressure pipe from Lutry ends. So as to be able to supply the northern quarters of Lausanne with water, a pumping station was put up here with a transformer station 3000—6000/380/220 V, 50 cycles, which also supplies the Montétan quarter. This pumping station (Fig. 8) is connected to the new La Châblière reservoir and the two Calvaire reservoirs, which two latter have a total capacity of 15,700 m^3 and are at 584 m altitude. The pumping station contains three sets of motor-pumps, one of which is a spare. The set connected to the La Châblière reservoir is designed for automatic operation by float or else for hand operation, while the Calvaire set is only for hand operation for the present. The three pumps are driven by three-phase induction motors with centrifugal starters, each of 100 kW at 1500 r. p. m., the pumps delivering 5000 l/min against a total head of 75 m for the Châblière reservoir and 3000 l/min against a total head of 130 m for the Calvaire reservoir. The third pump, which acts as a spare is built to deliver 4000 and 3000 l/min and against a total head of 75 and 130 m.

These sets are operated from the panel on the right in Fig. 8. This panel carries the apparatus necessary to allow the La Châblière set to be operated by hand, by push-button control or, automatically, by the float, by means of a relay mounted on the left panel; it also carries the apparatus for push-button operation of the Calvaire set. A selector on the right panel allows of putting the spare set to work in the place of either of the two sets, while using the starting up gear of the respective motors. The first of these panels is connected by cables to the low-voltage switchgear of the transformer station located above the pump room. This apparatus is mounted in cells and comprises per motor:— three heavy-current fuses, a three-pole contactor, three thermal maximum current relays and a special protective relay combined with a centrifugal switch, on the motor shaft end, which acts as a protection to the centrifugal starter. The special protection is necessary as this pumping station works without supervision.

3. The *La Châblière* and *Calvaire pumping stations.* — The Service des Eaux had two further motor-pump sets put into the rooms adjoining the Châblière and Calvaire reservoirs in order to be able to supply lake water to the whole town. The pump set in La Chablière consists of a 37-kW motor at 3000 r. p. m. with centrifugal starter direct-coupled to a centrifugal pump delivering 1200 l/min against a total head of 115 m. This pump drives water from the La Châblière reservoir to the Bellevaux reservoir situated at an altitude of 610 m. The second pump set drives water from the Calvaire reservoir to the Montblesson reservoir holding 1000 m^3 and situated at 699 m altitude. This set consists of a 90-kW motor at 3000 r. p. m. with centrifugal starter direct coupled to a centrifugal pump delivering 2500 l/min against a total head of 145 m. Both sets are hand-operated through switch boxes with thermal tripping devices.

The Lutry station was started up in December 1932 except the 450-kW motor, which was put to work in December 1933. The Montétan pumping station has been working since March 1934 and the La Châblière pumping station since July 1934. The Calvaire pumping station was put to work in December 1934.

All the electric equipment described, as well as the blower at 11 200 r. p. m. with its reduction gear, was delivered by Brown Boveri.

(MS 901) *P. Robert. (Mo.)*

THE RAPID DETERMINATION OF PIPE SIZES AND PRESSURE DROP IN STEAM PIPE INSTALLATIONS.

Decimal index 621. 186. 3.

THE factor which ultimately determines the size of pipe to be employed in a steam-pipe installation is the allowable pressure drop between the point of supply and the consuming device.

The calculation by ordinary methods of the pressure drop in a steam-pipe system is a long and tedious process. The charts I, II and III have been prepared to enable this pressure drop to be determined rapidly, without referring to steam tables or performing any calculations other than a simple summation of the pressure drops in the component parts of the pipe system. They have been drawn in such a manner that each stage of the computation can be clearly followed. These charts are equally convenient for determining the steam velocity and pressure drop corresponding to a given pipe diameter or the pipe diameter, and from the latter the pressure drop, corresponding to a given steam velocity. Ordinarily, the problem is to determine the size of pipe which will allow the passage of a given steam quantity without exceeding the maximum admissible pressure drop. The procedure is then as follows:—

Chart I enables a provisional value to be fixed for the pipe diameter on the basis of an assumed value of the steam velocity selected from Table A.

Table A. Provisional steam velocities.

Steam quantity tons/h	Velocity m/sec	
	Saturated steam	Superheated steam
1—10	20	30
11—100	30	45
Over 100	40	60

The pressure drop in the straight portions of the pipe is then determined with the aid of chart

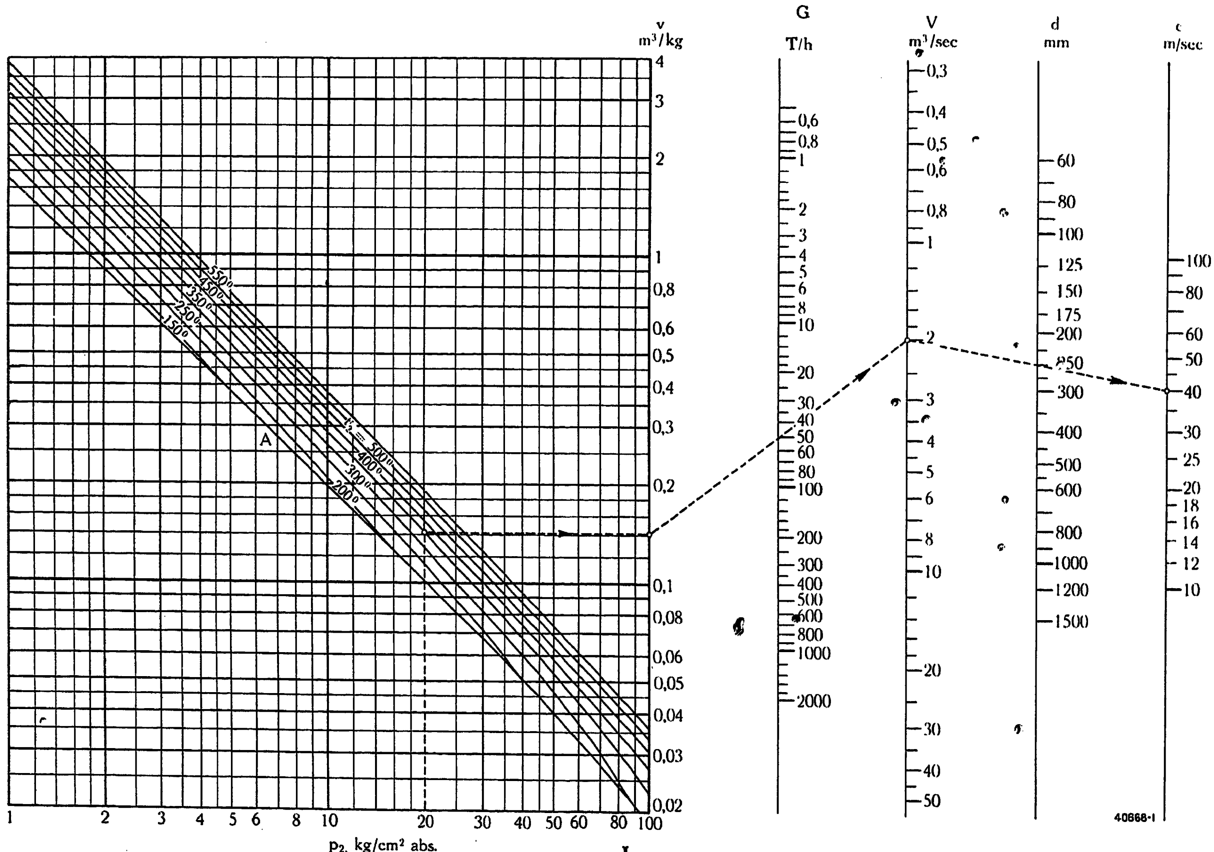

Fig. 1. — Chart I. Determination of the velocity of flow and diameter of steam pipes.

A. Saturation line.
c. Steam velocity in m/sec.
d. Pipe diameter in mm.
G. Steam quantity in t/h.
p_2. Absolute pressure at receiving end in kg/cm².
t_2. Steam temperature at receiving end in °C.
v. Specific volume of steam in m³/kg.
V. Volume of steam flowing per second in m³/sec.

II, and that in the bends and fittings with the aid of chart III and Table B.

The net pressure difference $p_1 - p_2$, between the point of supply and the consuming device, is equal to the sum of the pressure drops in the straight portions and in the various fittings, and of the static head due to any difference of level of the pipe ends, or.

$$p_1 - p_2 = \frac{L}{100} \cdot (\Delta p/100m) + \sum (k \cdot \alpha) \pm \frac{\gamma h}{10,000}$$

The first term on the right-hand side represents the pressure drop in the straight portions of the pipe, L being the total length of the pipe in m, and $(\Delta p/100m)$ the pressure drop per 100 m of straight pipe from chart II. The second term represents the sum of the drops in the various bends and fittings, the symbol Σ here denoting a summation of $(k \cdot \alpha)$ terms. The factor α which is obtained from chart III depends on the steam conditions the steam quantity and the pipe diameter, and is multiplied by the appropriate coefficient k from Table B in order to obtain the pressure drop in the individual fittings.

Table B. Value of coefficient k in the expression $\Delta p = k \cdot \alpha$ giving the pressure drop in bends and fittings.

Fittings	k
Standard bend	0·4
Smooth bend	0·15
Sharp elbow	1·5
T-joint	3·5
Globe or angle valve	5·0
Full-way gate valve	0·25

The last term on the right-hand side of the expression for the pressure difference at the pipe ends is the static pressure head where h is the difference in level, in m, and γ the specific gravity of the steam. This term is positive or negative respectively, according to whether the consuming device end is higher or lower than the supply end. In most cases, the difference in level h is small so that this term is negligible and can be omitted. When it is taken into account, it is not necessary to look up in steam tables the value of the specific gravity γ, as this is equal to the reciprocal of the specific

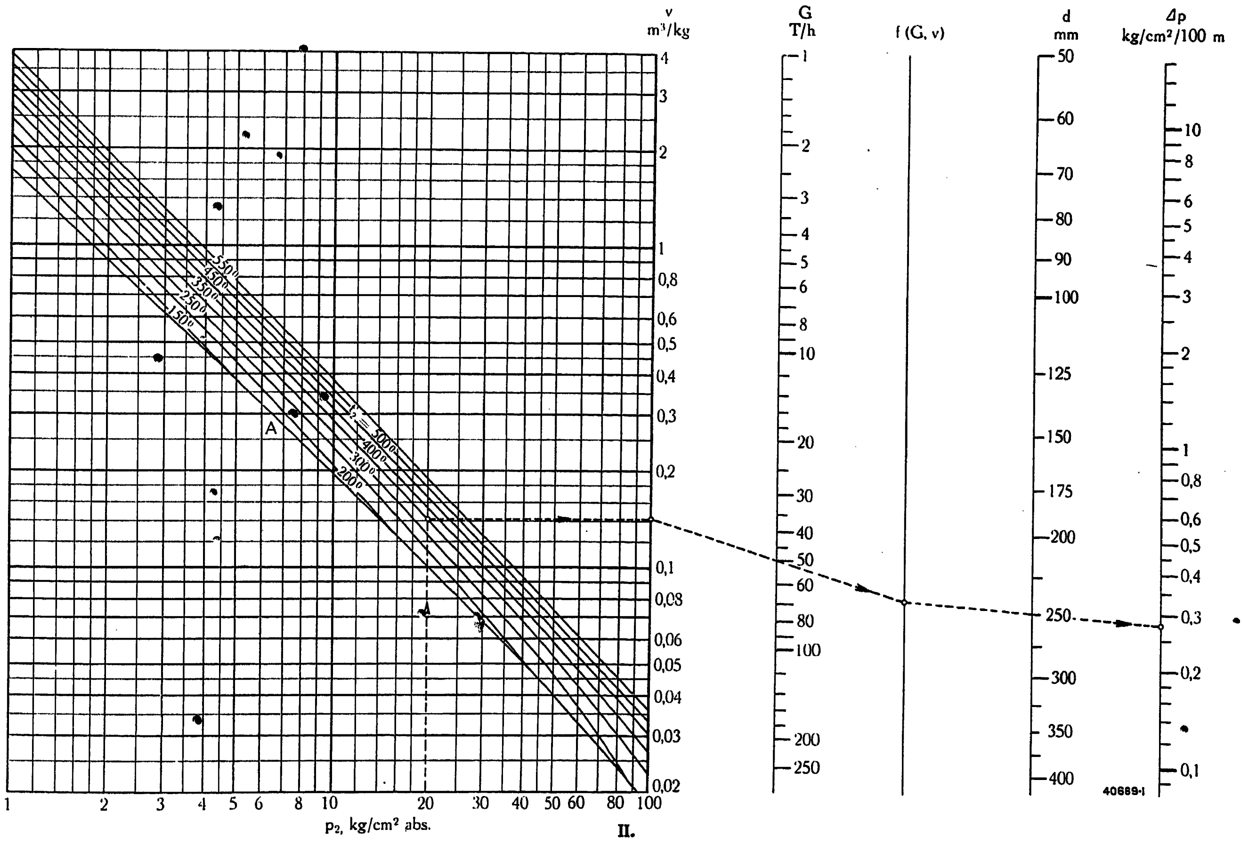

Fig. 2. — Chart II. Determination of the pressure drop in straight lengths of steam pipes.

A. Saturation line.
d. Pipe diameter in mm.
f (G, v). A function of G and v.
G. Steam quantity in t/h.
Δp. Pressure drop per 100 m of straight piping in kg/m².
p_2. Absolute pressure at receiving end in kg/cm².
t_2. Steam temperature at receiving end in °C.
v. Specific volume of steam in m³/kg.

volume v, which can be obtained from any of the charts I, II or III; or,

$$\frac{\gamma\ h}{10{,}000} = \frac{h}{10{,}000\ v}$$

In using these charts, the pressure and temperature conditions to be based upon are those at the receiving end (p_2, t_2), and not those at the supply end (p_1, t_1).

The use of the charts is best understood by their application to a particular case. Let it be desired to determine the size of pipe required for transmitting a maximum quantity of 50 t/h, pressure and temperature at the consuming end 20 kg/cm² abs, 350° C, maximum allowable pressure drop 1 kg/cm². The pipe line contains 200 m of straight pipe, four standard bends, two smooth bends and one full-way gate valve. The receiving end is 28 m lower than the supply end.

Using Chart I, start from the 20 kg/cm² point on the pressure scale and follow the dotted line up the 350° C temperature line to obtain the specific volume v=0·142 m³/kg. Lay a straight edge passing through this point and the 50-t/h point on the steam quantity scale and obtain the volume of steam flowing per second V=1·96 m³/sec.

According to Table A, the provisional value to be adopted for the steam velocity corresponding to a quantity of 50 t/h is 45 m/sec. Set the straight edge, therefore, so that it passes through the 1·96 m³/sec point on the volume scale and the 45 m/sec point on the velocity scale. The pipe diameter thus obtained is slightly less than 250 mm. The latter is, however, the nearest standard size and must accordingly be employed. Readjustment of the straight edge shows the steam velocity corresponding to a pipe diameter of 250 mm to be approximately 40 m/sec.

Chart II is next used in a similar manner to obtain the pressure drop in the straight lengths of pipe. In the example, the pressure drop per 100 m is 0·28 kg/cm², or 0·56 kg/cm² for 200 m.

The pressure drop over bends and fittings is given by the formula $\Delta p = k \cdot \alpha$. Chart III gives the value of α=0·058 and, selecting the appropriate values of the coefficient k from Table B, the pressure drops over the various fittings are:—

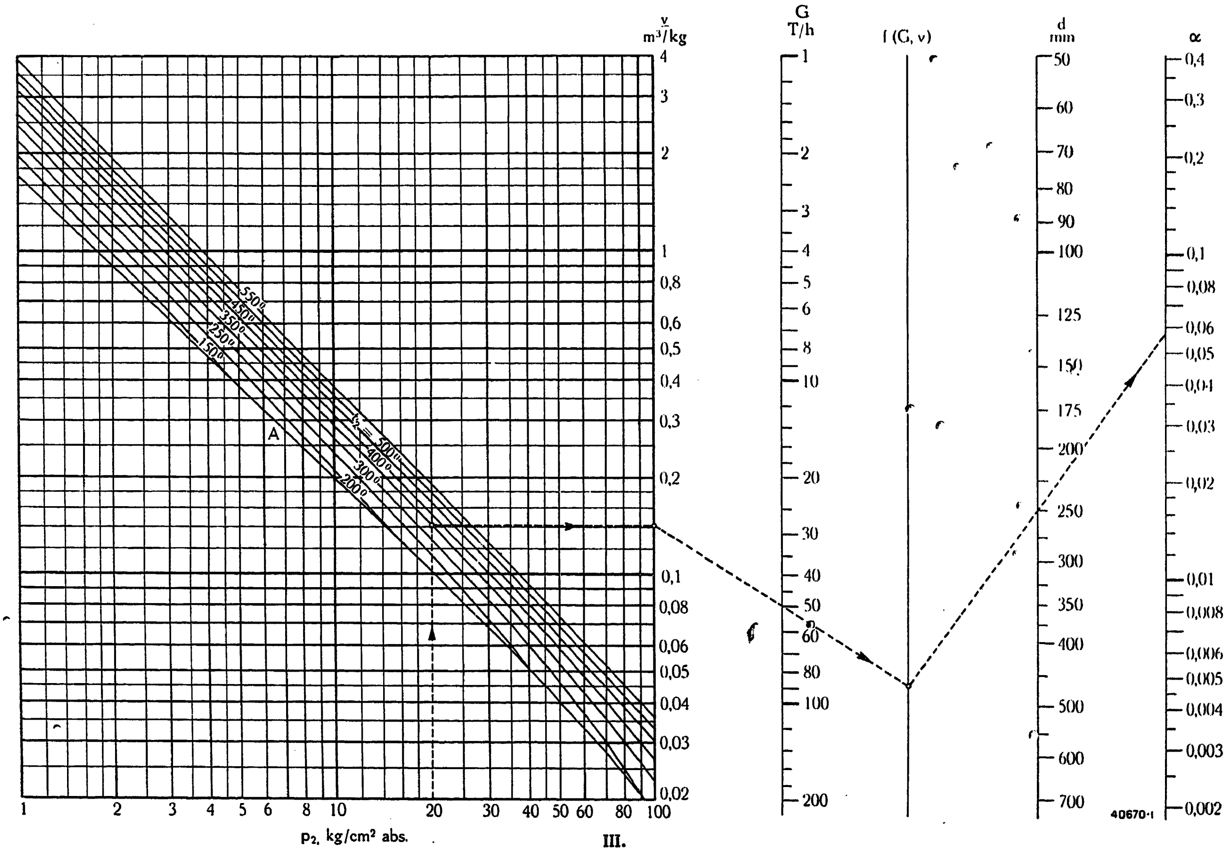

Fig. 3. — Chart III. Determination of the pressure drop in steam pipe fittings.

α. Factor in the expression $\Delta p = k . \alpha$ giving the pressure drop, k being obtained from Table B.
d. Pipe diameter in mm.
f(G,v). A function of G and v.
G. Steam quantity in t/h.
A. Saturation line.
p_2. Absolute pressure at receiving end in kg/cm².
t_2. Steam temperature at receiving end in °C.
v. Specific volume of steam in m³/kg.

4 standard bends	$4 \times 0{\cdot}4 \times 0{\cdot}058 = 0{\cdot}0928$
2 smooth bends	$2 \times 0{\cdot}15 \times 0{\cdot}058 = 0{\cdot}0174$
1 full-way gate valve	$1 \times 0{\cdot}25 \times 0{\cdot}058 = 0{\cdot}0145$

Total drop over bends and fittings:— $0{\cdot}1247 \mathrm{kg/cm}^2$.

The supply end of the pipe is 28 m higher than the consuming end so that the static head to be overcome is negative and equals:—

$$\frac{h}{10{,}000\ v} = \frac{-28}{10{,}000 \times 0{\cdot}142} = -0{\cdot}0197 \mathrm{kg/cm}^2$$

The net pressure difference between the supply and the consuming ends of the pipe line is therefore:—

$$p_1 - p_2 = 0{\cdot}56 + 0{\cdot}1247 - 0{\cdot}0197 = 0{\cdot}665 \ \mathrm{kg/cm}^2.$$

This value is within the given allowable limit of 1 $\mathrm{kg/cm}^2$, and a 250-mm diameter pipe is, therefore, satisfactory. Had the maximum allowable pressure drop been exceeded, it would have been necessary to repeat the calculation basing on the next larger pipe size.

This example brings out the fact that under usual conditions the static pressure head due to difference in level of the pipe ends is negligible and need only be taken into account when this difference in level is of the order of 100 m or over.

The resistance offered to the steam flow by the various valves and fittings necessarily varies considerably, not only due to differences of design, but also according to their disposition in the pipe system and the direction of steam flow. The values of the coefficient k given in table B are such that the pressure drops calculated are liberal average values.

In order to allow for the pressure drop across expansion pieces, it is convenient to express their resistance in terms of equivalent length of straight pipe. The equivalent length of straight pipe for U or lyre-shaped expansion pieces is twice the extended length and for corrugated or bellows expansion pieces five times their length. Steam separators and strainers vary so greatly that it is impossible to give an average value of k to enable the pressure drop in them to be calculated. Nevertheless, in order to make an approximate allowance for such devices, and, in the absence of more exact data, it is convenient to take their resistance as equal to that of a standard globe valve.

(MS 902) *H. S. Hvistendahl.*

A SIMPLE CONTROL FOR INSPECTION CARS AND MOTOR COACHES DRIVEN BY INTERNAL COMBUSTION ENGINES.

Decimal index 621.337.1.

THROUGH personal observation and descriptions in technical journals and the daily press, the public is fairly well informed on the subject of the rolling stock used in standard railway service. On the other hand, those not directly connected with railways are almost entirely ignorant of the numerous vehicles which are not to be seen, every day, in railway stations or encountered on main lines, although the vehicles in question render indispensable services and play an important part in maintaining organized service.

Apart from the numerous small rail cars such as hand cars, inspection trolleys, etc., used for the supervision of the line and for taking workmen from one point to another, many railways employ bigger vehicles for special purposes. Among these are tunnel-inspection cars, crane or derrick cars, repair cars of various kinds. When required, these cars are, usually, brought to the required site by a locomotive. On electrified railways, special cars are required, apart from light ladder cars, for supervising and repairing the contact wires and these vehicles must be able to accommodate sufficient tools as well as material for making big repairs. As there are, frequently, no steam locomotives available, it is practical to equip these cars with their own driving machinery and the demands made on the latter are far from being as light as might appear at first.

One of the essential conditions is simplicity of the control which must be such that it can be exercised by unskilled labour, while instant readiness for service is another important condition. A fairly high maximum speed is desirable as defects on the contact wire generally mean considerable disorganization of service and they must be eliminated, for this reason, as promptly as possible. On the other hand, very close speed regulation in the range of lowest speeds (5—10 km/h) is necessary and the inspection car must be able to haul one or two cars with repair material, on which are placed the cable drums for the contact wire and line-supporting parts etc. Finally, the first cost and upkeep charges must be low as these cars are only used occasionally. For the same reason, fuel and lubricating-oil charges are not a factor of importance.

Usually, storage-battery cars do not meet the requirements on account of their heavy weight and

high cost. For this reason, the internal combustion engine is used, practically exclusively, either as a carburettor engine or as a Diesel engine, with direct mechanical drive of the axles or with electric power-transmission. An investigation must be carried out, from one case to another, to determine which is the best type of engine, taking as principle factors the cost of purchase and the number of hours of service per year which seem probable. The space available for the engine, the noise it makes and fumes it produces when running are also factors to be considered. As regards weight alone, mechanical power transmission on the car is slightly superior to the electric power transmission, but it presents difficulties with respect to speed graduation in cases where close regulation at low speeds is called for simultaneously with a high maximum speed. There is no doubt that electric power transmission is easier as regards control. When the machinery and control gear are suitably arranged, the higher cost of the car with electric power transmission only comes to a very small percentage of the total cost of the car. Electric power transmission is frequently chosen owing to the numerous advantages it gives in service.

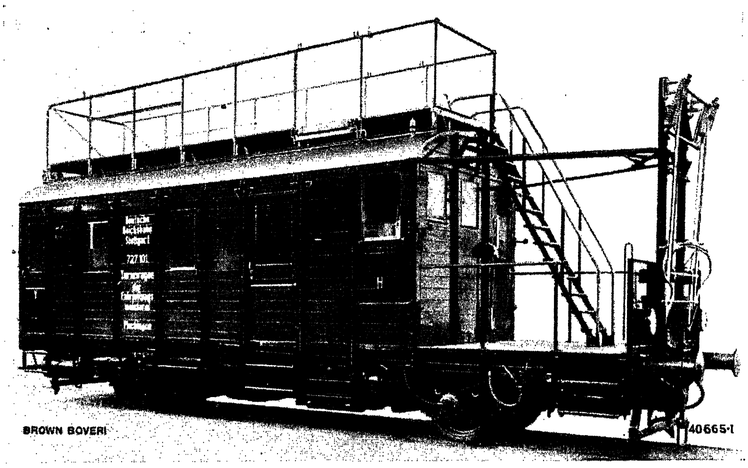

Fig. 1. — Petrol engine-electric contact-wire inspection car, of the German State Railway Company.

On the occasion of the introduction of electric-train traction on the Augsburg-Stuttgart line section of the German State Railway Company, the management of the latter ordered a petrol engine-electric inspection car from the Esslingen Machine Works, after having first carefully weighed the pros and cons of different types of drive. Brown Boveri, Mannheim delivered the electric equipment of this car. To take into account the particular conditions specified, a new type of control (DRP) was developed which will be described here.

The 12-cylinder Maybach petrol engine delivers 165 H.P. at 2600 r. p. m. It drives the generator set through a flexible coupling. The main generator supplies power to a nose-suspended motor equipped with separate fan ventilation, which has a one-hour rating of 160 kW. This motor drives one of the two axles through a spur-wheel gear of a ratio of 1 to 3·48. The driving wheels have a diameter of 1000 mm. The one-hour tractive effort is 1740 kg and the maximum starting tractive effort is 3200 kg. Ready for service, the car weighs 23 t and it has a maximum speed of 75 km/h. It can haul a trailer load of up to 40 t. Alone and on a 22·5 ‰ gradient it attains 43 km/h and with a 15-t trailer load, 28 km/h. An auxiliary generator direct-coupled to the main generator is used to supply the auxiliaries, such as lighting, battery charging, separate excitation of the main generator etc. The condition was imposed for the electric machinery that the REB rules as regards temperature rise, when running at constant speed of 6 km/h with a 15-ton trailer load on a 22·5 ‰ gradient, should not be exceeded.

The general diagram of connections shown in Fig. 2 allows of following the way the control works. As is usual in vehicles having internal combustion engines, the main generator is provided with a counter-compound winding. A shunt field winding, which is not regulated, is utilized to keep the working range of the power regulator inserted on the separate excitation as low as possible.

The driver's handwheel controls the speed governor of the petrol engine through the agency of a

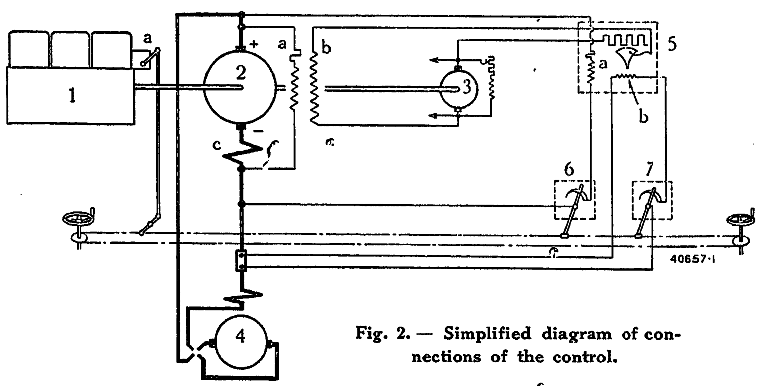

Fig. 2. — Simplified diagram of connections of the control.

1. Petrol engine (a. Speed governor).
2. Main generator (a. Shunt winding; b. Separate excitation; c. Counter-field winding).
3. Auxiliary generator.
4. Traction motor
5. Power regulator (a. Voltage coil; b. Current coil).
6. Rheostat in voltage-coil circuit.
7. Rheostat in current-coil circuit.

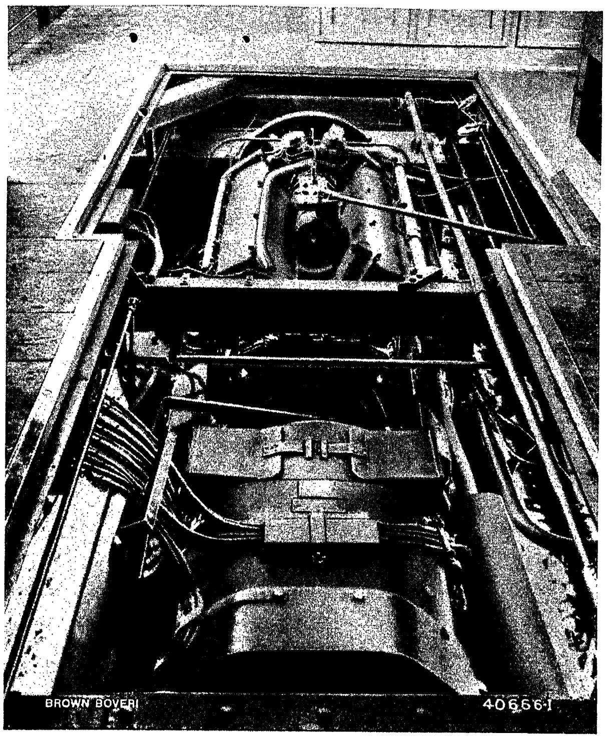

Fig. 3. — Petrol engine and generator built in under the car floor.

cable, which allows of regulating the speed between 1200 and 2600 r. p. m., as desired. The power available varies according to the speed. A special lever allows of setting the no-load speed at about 600 r. p. m.

The duty of the electric equipment is to transmit the power of the petrol engine made available at its various speeds to the driving wheel tread. As the strength of the current taken by the driving motor is determined by the tractive effort demanded, which, in its turn, depends on the train load and the gradient being negotiated, the voltage of the main generator must be altered according to the engine power available. This is done by means of a power regulator of the well-known Brown Boveri quick-acting regulator design, which acts on the separate excitation. The output of the generator which the power regulator holds constant must always correspond to that developed by the petrol engine at the speed the driver has regulated to. This condition is fulfilled by actuating two rheostats by the same cable which regulates the speed governor of the petrol engine. These two rheostats change the resistance in the circuit of the voltage coil and in that of the current coil of the quick-acting regulator so that the latter adjusts the output to the desired figure. By suitable choice of the resistance steps, every partial load or full load of the engine which the manufacturer of the latter considers advantageous for different speeds can be made to correspond to these speeds. Thus, inadmissible stressing of the engine is eliminated. The characteristic of the power regulator takes into account the fact that at given loads and speeds the efficiency of the main generator under heavy currents and low voltages is not so high as under low currents and high voltages.

The control equipment described has, apart from its advantageous regulating qualities, the advantage of taking up very little space and of being very light. In the contact-wire inspection car of the German State Railway Company, the quick-acting regulator and its resistances are lodged under a bench inside the car. The apparatus only weighs 40 kg. The rest of the machinery is placed under the car floor as shown in Fig. 3.

The specified conditions were such that, with the type of control just described, the output to be held constant was about 109 kW in the highest step and 6 kW in the lowest. In many cases, it is not necessary to hold the output constant in the lowest range of speed of the petrol engine, and the output can be allowed to vary in this range, according to the generator characteristic. The control equipment can then be simplified still further, the rheostat inserted in the current coil circuit of the power regulator being left out.

As a result of the satisfactory experience gained with the first inspection car of this kind, which was put into service at the beginning of 1934, the German State Railway Company has now purchased three other cars with the same Brown Boveri control equipment. The latter can, of course, be used on other vehicles, as well.

(MS 899) *H. Margot. (Mo.)*

NOTES.

The Velox heat generating plant in the central-heating installation of the Cantonal Hospital Aarau (Switzerland).

Decimal index 621.181.39 (494).

WHEN the existing buildings of the Aarau Cantonal Hospital were extended, recently, it became necessary to put in a new central-heating plant, the output of the old one being no longer adequate.

Under ordinary circumstances, the whole heating requirements of the hospital are covered by electrically generated heat. Waste power from the municipal power supply system was used for this purpose, the kWh price of which is much cheaper than that of power at ordinary metering terms. The electric-power requirements of the establishment cannot, however, always be met by the power supply system and special measures had to be taken in order to make up the difference between the power available and the heating requirements. At those seasons of the year when water is scarce, which, in Switzerland, occur in January and February, that is to say precisely when the power requirements for heating are greatest, it may happen that there is no electric power at all available for heating. Thus, a spare source of heat is absol-

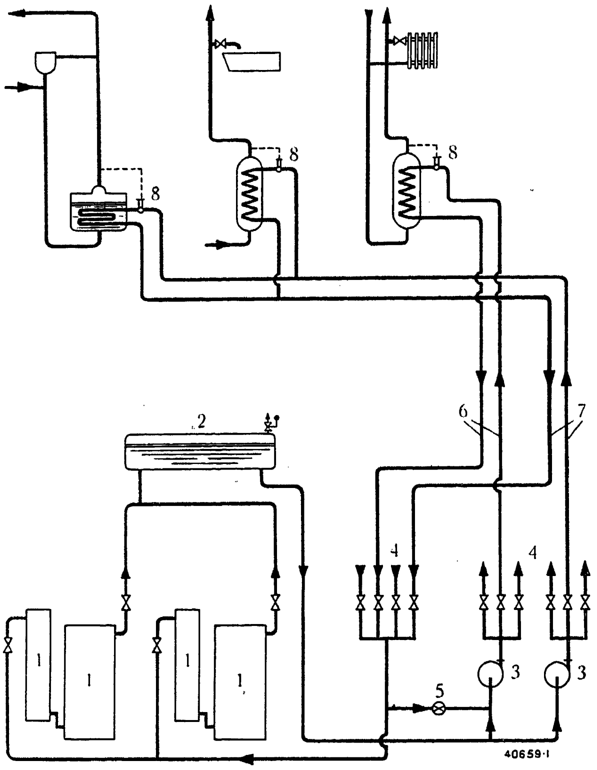

Fig. 1. — Diagrammatic illustration of a hot-water plant with Velox heat generators and the heat distributing system belonging thereto.

1. Velox heat generator with preheater.
2. Compensating tank.
3. Circulation pump.
4. Distributor.
5. Mixing valve.
6. Outgoing and incoming pipe, for hot water for heating rooms.
7. Outgoing and incoming pipe for cooking, baths and washing etc.
8. Hot-water-thermostat governing device.

utely necessary, either in the form of coal or oil-fired boilers.

After careful investigation of all the plans submitted to them, the authorities entrusted with the extension of the Aarau Cantonal Hospital decided on the purchase of Velox heat generators. One of the chief points in their favour and which makes them eminently suitable as spares, in this and in similar cases, is their continuous readiness for service, which is unequalled. As is known, the Velox can be brought up from cold condition to full load delivery in the space of a very few minutes. Thus, in the present case, there is no danger of the heating system failing even for a short time although the current supply be cut off suddenly. The central heating system is so extensive that the amount of heat circulating is quite sufficient for the needs of the establishment during the short time the Velox is being got under load.

In the Aarau Cantonal Hospital the heat distribution is carried out by means of the modern hot-water system, in the long feeder pipes of which temperatures of as much as 190° C are used and pressures which are correspondingly high. The heat is distributed in the different blocks of buildings through secondary circuits, after passing through heat exchangers; the temperatures and pressures in the secondary circuits being of the usual order.

The diagram given here shows how the Velox is linked up to the heat distributing system (Fig. 1). There is a compensating tank inserted between the Velox and the system, which is dimensioned so as to be able to take up the variations in the volume of water of the entire system. The water flowing back from the heating system reaches the Velox through the economiser and leaves the Velox at a maximum temperature of about 190° C. The heat-distributing system is in closed circuit and is under pressure which must be equal to or greater than the steam saturation pressure corresponding to 190° C, that is to say, at least 13 kg/cm^2 abs this in order to prevente vaporation taking place at any point on the circuit. The pump which is used to force the water through the heat distributing system is also used to drive the heating water through the economiser and the Velox (this pump was delivered by the firm which built the heat distributing system). The central heating plant is equipped with two Velox heat generators, each designed for delivering 7 millions kcal/h, which corresponds to the heat output of a steam generator of about 10 t/h. Gas oil as well as heavy Mazout can be used as fuel. The design is essentially the same as that of the Velox steam generator. It differs from the latter by being still simpler, as a steam separator and steam superheater are done away with. There is also no automatic regulation of combustion. Hand governing is quite sufficient owing to the big heat capacity presented by the distributing system and as, further, there is a heat accumulator on the system.

According to heat requirements and the amount of electric power available, both Velox units can be made to work in parallel or else one Velox working with one electric boiler can cover the requirements of the establishment.

The illustration on the cover of this number shows the two Velox units in the machine hall, while Fig. 2 shows the switchboard holding all apparatus and instruments

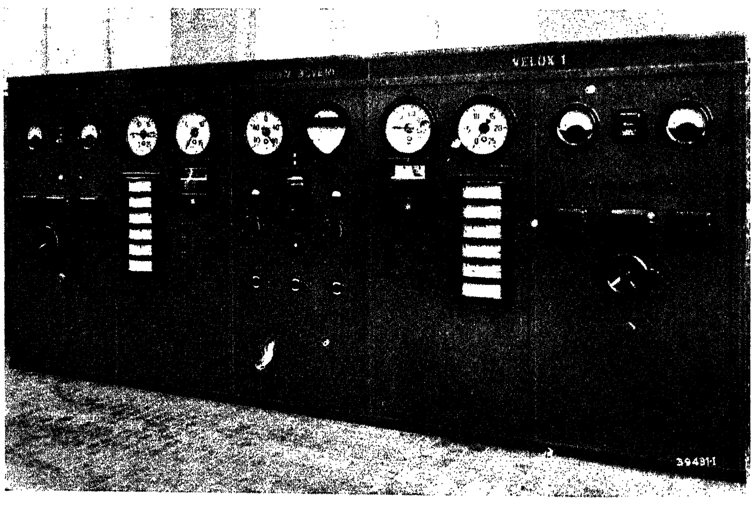

Fig. 2. — Switchboard with all apparatus and instruments necessary to operate the Velox heat generator.

required for service and measurements. The Velox is started up by push-button from the said switchboard. A more detailed article on this plant will be published later.

(MS 896) *W. Roth. (Mo.)*

Rolling-mill motor with speed regulation according to the Kraemer system, for the Compañía Anónima Basconia, Bilbao.

Decimal index 621.34:621.771.

SPEED regulation of a three-phase motor by means of a D. C. motor, which is mechanically coupled to it while being electrically connected in cascade to its slip rings, through a rotary converter, presents many advantageous features for the drive of rolling mills. This system of speed regulation is used, in practice, for average and big outputs only and is especially suitable when the range of speed regulation attainable with the Brown Boveri Scherbius system (see The Brown Boveri Review, November-December 1930) no longer suffices and when, nevertheless, the use of D. C. motors would not be justified by the range of speed required.

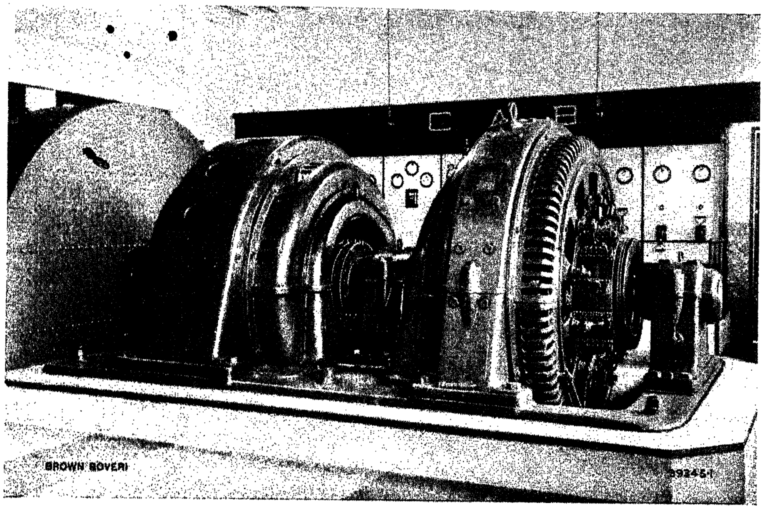

Fig. 1. — Rolling-mill motor, 1850 kW, 3000 V, 50 cycles, 600 r. p. m. with auxiliary D. C. motor for speed regulation, according to the Kraemer system, between 540 and 300 r. p. m., at constant output.

With the Kraemer regulating system, the slip energy of the three-phase motor is transformed into D. C. energy by passing it through a rotary converter. The latter supplies a D. C. motor direct coupled to the main motor. It is, then, very easy to regulate the speed of the main motor by acting on the excitation of the D. C. motor. In this way an additional voltage is impressed on the slip rings of the main motor thus causing the speed of the latter to vary.

As rolling mill drives are often equipped with flywheels, it is necessary to allow of a certain speed drop of the driving motor in function of the load, in order to permit the flywheel to produce its effect. To this end, an indirect compounding of the D. C. auxiliary motor is used. This is effected by means of a shunt inserted on the main D. C. circuit from which an auxiliary winding of the excitation of the D. C. motor is supplied. A rheostat in the circuit of the compound winding allows of adjusting the speed drop to whatever the requirements of the mill may be. The Kraemer regulating sets are highly appreciated for rolling mill drives where, as is well known, service conditions are severe, thanks to the simple regulating devices, the high efficiency and power factor and also, to a great degree, to the composition of the regulating set, which only contains standard machine units easy to attend and repair.

Brown Boveri built many of these sets and, lately, delivered a three-phase rolling-mill motor, 1850 kW continuous rating, 3000 V, 50 cycles to the Compañía Anónima Basconia in Bilbao, the speed of this unit at constant output being varied by the Kraemer system between 540 and 300 r. p. m. The motor set is shown in Fig. 1 and, consists of a ten-pole three-phase motor direct-coupled to an auxiliary D. C. motor to drive a finishing rolling mill, through a reduction gear on the pinion shaft of which two flywheels are mounted, one on each side. Fig. 2 shows the rotary converter belonging to the equipment, with the liquid starter, the excitation set and the distribution switchboard panel.

With the Brown Boveri connections, there is no circuit breaker on the main D. C. circuit, which simplifies both switchgear and distribution leads, considerably. Two field switches protect the D. C. machines against overloads. These switches cut out the respective excitations of the machines and short-circuit them through suitably dimensioned resistances. Simultaneously, the main switch on the three-phase side is opened, which cuts off voltage from the regulating set, immediately.

The switchboard panel carries a rheostat, which allows of adjusting the power factor with the help of a p. f. indicator. There are two further rheostats for speed regulation, one being mounted in the panel and the other on the control gangway of the rolling mill. The excitation circuit can be connected up to either of these rheostats through a small change-over switch.

A further interesting device opens the main circuit breaker on the three-phase side if the leads from the

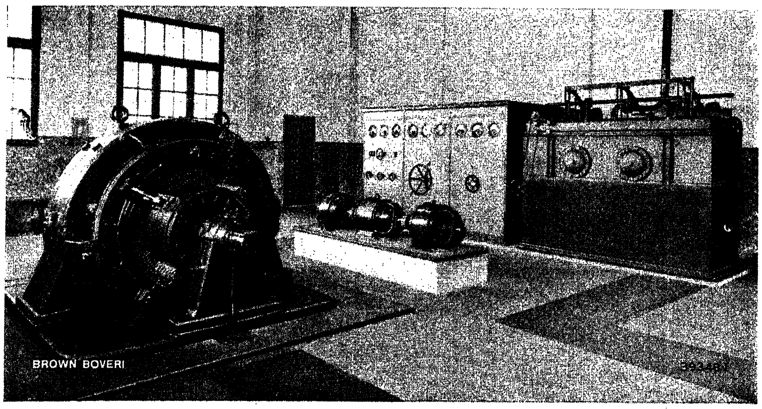

Fig. 2. — Rotary convertor, liquid starter, excitation set and distributing switchboard for a Kraemer regulating set of 1850 kW output.

supply system are cut out, intentionally or accidentally. A no-volt releasing device would not function in this case as the three-phase motor excited from the D. C. side would run as a generator owing to the power stored up in the flywheels. It would go on feeding power back to the system for a certain length of time, though at a falling frequency. This would cause trouble and be dangerous to the operators who might well be led to think that having cut out the supply leads the plant was dead. In order to eliminate this drawback, a frequency relay was built in, which opens the main switch of the motor when the frequency falls below a certain figure.

(MS 892) *M. Rosset. (Mo.)*

Mutators for electrolysis, for the Steeg Aluminium Works (Austria).

Decimal index 621. 314. 652. 2 : 621. 357 (436).

In the autumn of last year, Brown Boveri were able to hand over, ready for service, the new mutator plant (8350 A, 360 V) for the electrolysis of aluminium in the Steeg Works (Austria); delivery and erection having taken hardly six months from date of order. As in all industrial electrolytic processes, the outlay for power and for power conversion plays an important part in calculating the cost of aluminium production. As regards efficiency of conversion, it has already been stated, here, that the yearly loss in power, when mutators are used, is in inverse ratio to the service voltage. When a plant is being rebuilt or a new plant put up it is, therefore, well worth while to examine whether it would not be advantageous to build the electrolytic plant so that the size of the furnaces, baths or cells for the yearly production aimed at, should be chosen according to the most advantageous operating voltage rather than according to a given electrolytic current strength. In the present case, however, the size of the existing furnace series did not allow of so doing, so that the rated voltage could not be increased beyond 360 V and the maximum above 440 V.

Although the overall efficiency attained by this plant of 89 % ± 1 % margin at 360 V and 8350 A (including transformer, choke coil, auxiliary and bus-bar losses) is a value which can be attained by motor generator sets, as well, the technical advisors of the present plant decided to put in mutators because of the satisfactory reports they got from other plants and the economic and technical advantages of this modern and silent type of convertor[1]. As the setting to work operations had given rise to no troubles at all and, owing to the fact that is was found possible to build up the current to its full-load value, immediately, the guarantee tests could be carried out just after the trial test. The overall efficiency measured from losses, at a mutator temperature of 45° C and a power delivery of 3000 kW, 360 V, was 89·25 % as compared to the guaranteed figure of 89 % ± 1 % margin.

In order to attain the most advantageous mutator cooling conditions in as simple a way as possible, the cooling is a combination of a closed-cooling system with fresh-water cooling. The heat generated by losses is turned to practical account by making use of it to heat the water of a bathing and washing establishment. Continuous regulation of the D.C. voltage over a relatively wide range is a condition insisted on in aluminium works, both by the operating engineer and the metallurgist, on account of the fluctuating resistance of the furnaces, the advantageous utilization of the power supplied and, finally, the quality of the raw material manufactured; this condition is fulfilled by using controlled grids which work without causing additional losses at all.

The system of connections which Brown Boveri use after exhaustive study of the question, allows of very precise setting of the anode ignition point and, therewith, a very exact regulation of the D. C. voltage. By rotating a small handwheel which displaces the contact track of the ignition distributor in relation to the brushes, which rotate synchronously, by means of a worm drive, it is possible

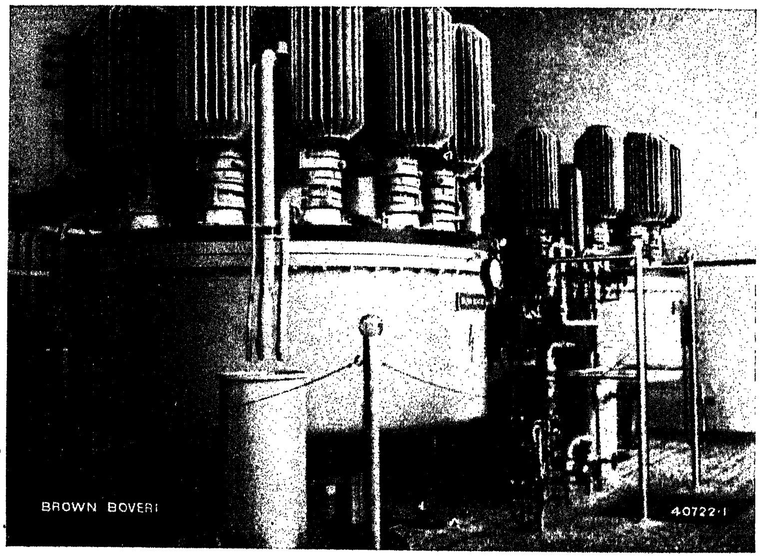

Fig. 1. — Mutator plant in the Steeg Aluminium Works (Austria), composed of a double set delivering 100 — 360 V, 8350 A, 3000 kW at 440 V.

to make the D.C. voltage of the furnace suit the ohmic resistance of the body being melted so that the series of furnaces work with the most advantageous current possible. When there are abnormally heavy voltage fluctuations (simultaneous flashes on several furnaces) or when there are changes in the grouping of the furnaces necessitated by service conditions, the D. C. voltage can, also, be adjusted to meet the new conditions by using a step switch which has a few widely spaced steps. In this way the power factor of the plant is maintained high and need only vary within a narrow range, which could not be done if the D.C. voltage had to be regulated by means of the controlled grids alone.

(MS 893) *A. Danz. (Mo.)*

[1] See The Brown Boveri Review, Number 12, December 1934:— "The A. C.—D. C. mutator for use in electrolytic plants".

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VOL. XXII SEPTEMBER, 1935 No. 9

THE BROWN BOVERI REVIEW

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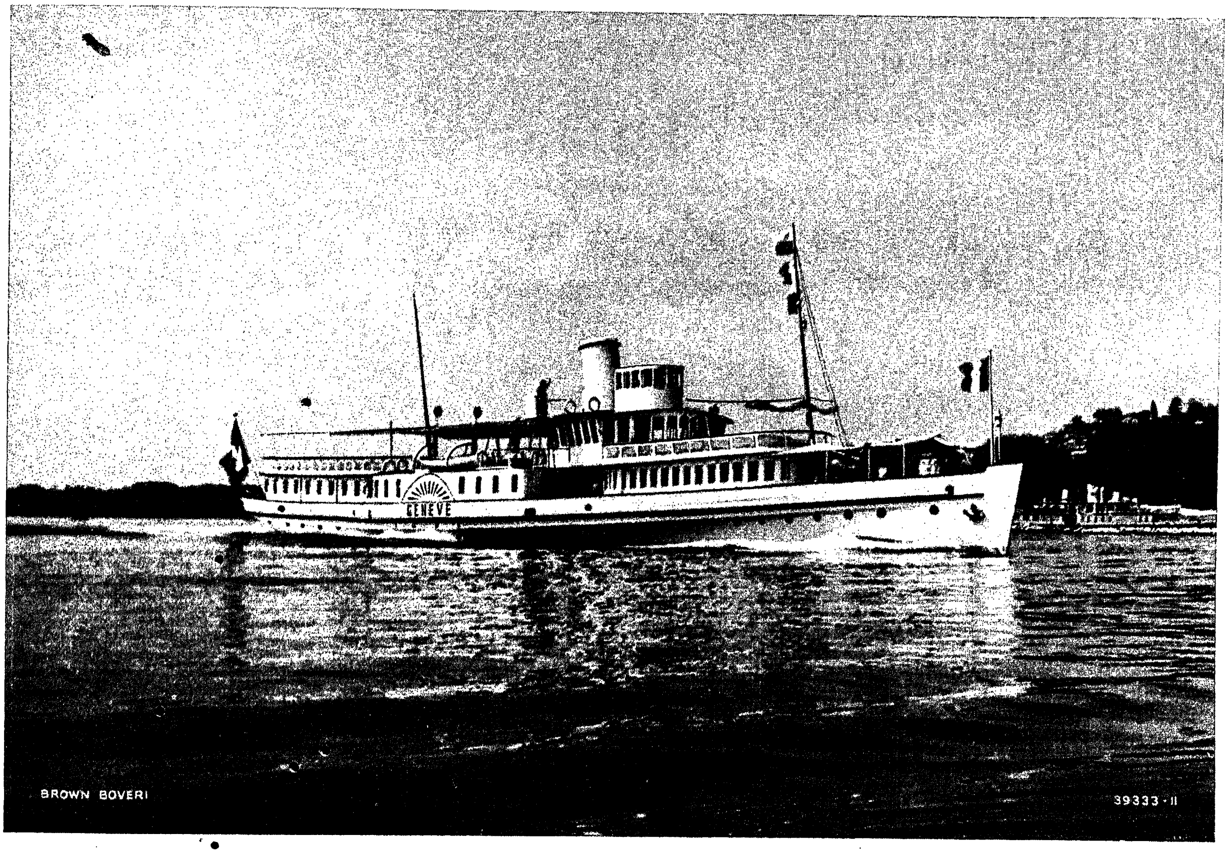


THE SALOON PADDLE VESSEL "GENÈVE" WITH DIESEL-ELECTRIC DRIVING PLANT.

CONTENTS:

Printed in Switzerland

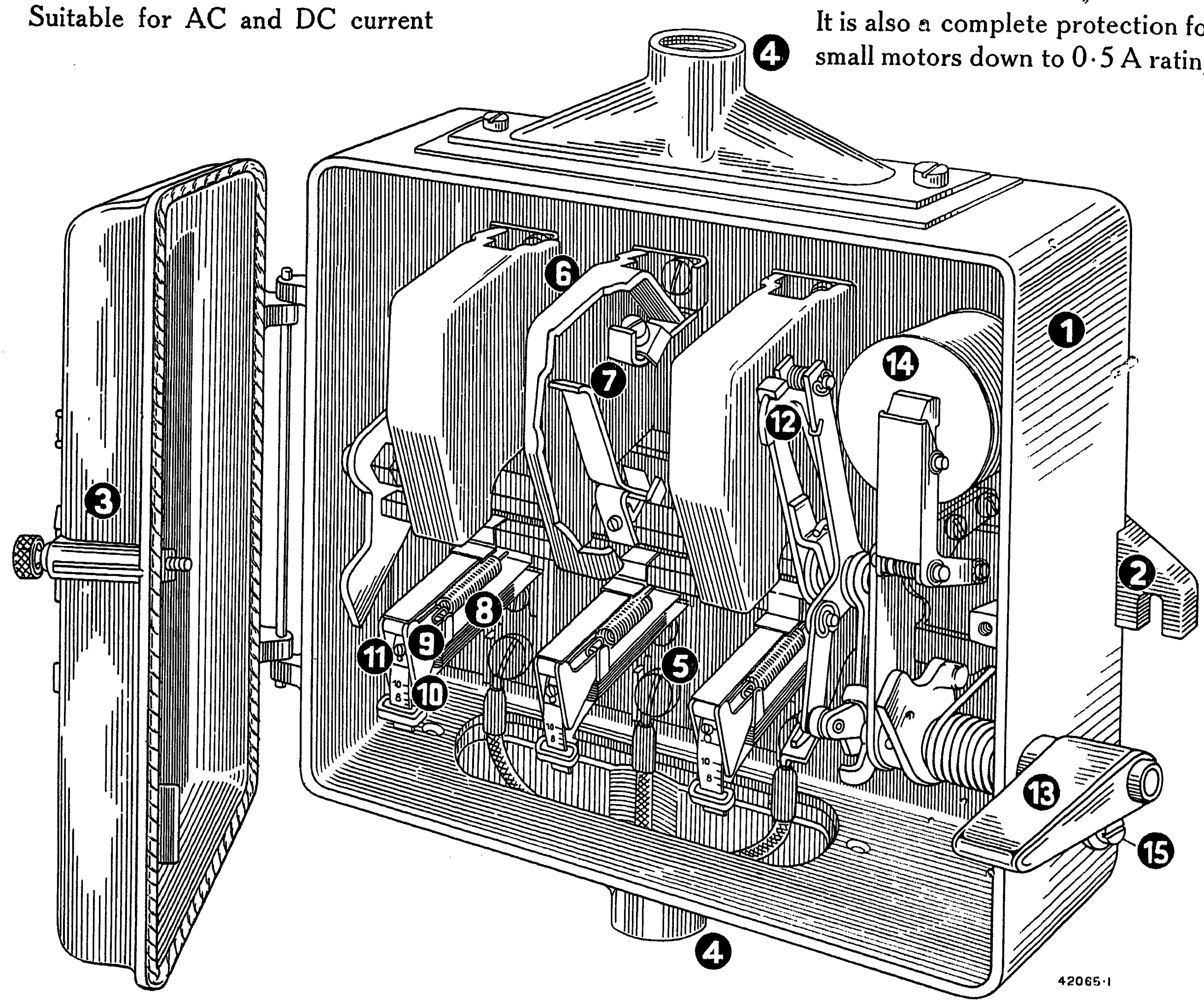
The three-pole switchbox Types N 2 and NK 2 with thermal releases

(Type N 2 without low-voltage release and NK 2 with low-voltage release)

is the best switch imaginable for protecting motors up to 25 A rating

Suitable for AC and DC current

It is also a complete protection for small motors down to 0·5 A rating



Some of the many advantages of this new switchbox are given herewith:—

1. Dust and splash-proof housing made of light metal (weight only 2·35 kg). Compact design, takes up little space.
2. Easy to mount by means of hooks. Generally mounted vertically but can be placed flat or inclined, as required.
3. Cover and switch interlocked. Lead seal can be added to prevent unauthorized manipulations.
4. Leads can be brought in as desired from above or below, or the switchbox can be mounted in line with the supply cable. Connecting branches designed for the most varied applications. (Steel conduit, cable, mounting in a switchboard.)
5. Specially designed terminals allowing of connecting up leads, simply and reliably, without having to form an eye.
6. Double terminals for through neutral wire.
7. Durable good contacts due to massive silver plating on the contact pieces, which are also easy to replace.
8. Brown Boveri thermal releases which years of experience have shown to be thoroughly reliable under the severest service conditions.
9. Combination of the thermal release with a trigger spring. This makes the release quite insensitive to small inaccuracies in fitting, for instance when the releases are changed against others of another current strength.
10. Combination of the thermal release with its setting device in such a manner that immediate reading of the setting is secured. It renders basic setting, which is often troublesome, unnecessary.
11. Setting to the rated current of the motor to be protected, that is to say in accordance with the rating-plate indications on the motor instead of according to some excess-current value which had first to be calculated.
12. Direct tripping by trigger action on the switch. After tripping, automatic return of the release to previous position, therefore, immediate readiness for taking up service again.
13. Insulated control handle. Free clutch securing tripping even if the handle is held in closed position.
14. No-volt coil.
15. Earthing serew.

Ample space, good supervision, great accessibility, no special tools required.

Can be connected up anywhere.

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXII SEPTEMBER, 1935 No. 9

The Brown Boveri Review is issued monthly. Single numbers: 1.20 francs. Annual subscription: 12 francs, postage and packing extra.

NEW DIESEL-ELECTRIC DRIVES OF BROWN BOVERI DESIGN, FOR SHIPS.

Decimal index 621. 34. 033. 44: 629. 12.

THE saloon paddle vessel "Genève" running on the Lake of Geneva and the Norwegian mine layer "Olav Tryggvason" with its Diesel-electric complementary drive used for cruising speeds are described herewith, some general observations on the control of Diesel-electric drives in ships being appended.

In No. 1/2 of this Review, year 1935, a summary report was given of these two Diesel-electric ship drives which had been put to work in the course of the preceding year. The following paragraphs give more complete information on the two plants in question and conclude with the above mentioned description of different types of control for Diesel-electric ship drives with special reference to the application of the Brown Boveri quick-acting regulator.

I. *The saloon paddle vessel "Genève".*

The paddle steamer "Genève" was built by Messrs. Sulzer Bros., Winterthur, in 1895/96 and is used for passenger traffic exclusively (accommodation 850 passengers) on the Lake of Geneva. The main characteristics of the vessel are:—

Displacement	332 t
Length B. P.	60 m
Breadth at main framing	6·75 m
Depth at side	2·7 m
Light draught	1·56 m
Output of former steam engine	690 H. P. at 43 r. p. m.
Corresponding speed	13·5 knots

In 1933, it became necessary to renew the boiler plant and the owners (Compagnie Générale de Navigation sur le Lac Léman) decided to change over from steam drive to Diesel-electric drive. Calculations showed considerable saving in running charges in favour of the Diesel drive. The decision to retain the side paddle wheels obviously led to the adoption of electric transmission of power from the Diesel engines to the paddle shaft. The next important question was whether the very slow running paddle shaft should be driven direct by a double-armature D. C. motor or else by electric motors of fairly high speed through a reduction gear and also if each paddle should be driven independently or, as heretofore, by a common shaft. It was decided that two electric motors of 500 r. p. m. would be used working through a reduction gear with a 1 : 10·5 ratio and that they should drive the two existing paddles through a common shaft.

Individual drive of the paddle wheels certainly gives the vessel a somewhat greater flexibility in manœuvring, especially in turning on itself, as one wheel can be rotated in one sense and the other in the opposite sense; the disadvantages are an increased stressing of the ship structure and also that, if one motor were disabled — an occurrence which, however, would probably be rare — one paddle wheel would be completely out of action, unless an emergency intermediate shaft to connect up the two paddle wheels were available. In spite of the fact that vessels on the Lake of Geneva have difficult manœuvring conditions to meet, individual paddle-wheel drive was rejected by the owners as undesirable and impracticable.

One of the advantages claimed for the direct drive of a common paddle-wheel shaft by a slow-running electric motor is its noiselessness, while another is that if one paddle wheel is suddenly stopped by running on to a sandbank or by foreign bodies such as floating blocks of wood getting jammed in the paddle box, no harm comes to the drive, because the flywheel effect of the rotating parts is relatively small and the link between the stationary part (stator) and the rotor of the driving motor is magnetic and not mechanical.

A mathematical examination of the conditions pertaining to the present case (two motors 500 r. p. m., gear ratio 1 : 10·5) and allowing for an abrupt blocking of the shaft within one quarter of a revolution from full speed (50 r. p. m.) shows that the retarding pressure created does not stress the gear teeth unduly and that the factor of safety against breaking a gear tooth is, even, as high as about four. If it is remembered that a paddle wheel has a certain elasticity of its own, it will be understood that conditions are, in fact, still less dangerous. Moreover, Brown Boveri was able to point to service experience over many years with the turbine-driven paddle tug "Dordrecht" which has given perfect service on the

Rhine since the year 1924.[1] In this latter case the dangerous elements due to the big flywheel effect of the high-speed turbine rotors and the overall gearing ratio of 1 : 95 between the paddle wheel and the turbine shaft were, in themselves, much more serious factors than in the case of the "Genève". In the "Dordrecht", the paddle-wheel shaft is connected to the shaft of the big gear wheel through an emergency rupturing coupling and a certain flexibility is introduced to the system by placing torsion shafts between the first and second gear steps. This plant has run now for ten years without any trouble which promises well for the solution of the driving problem of the "Genève" by geared electric motors. As regards the question of noise, there was nothing to fear, in the case of the "Genève", on account of the low peripheral speeds, and the reduction gear of the "Genève" has proved, in fact, to run noiselessly in the true sense of the word.

Fig. 1 shows the layout of the machinery, after the conversion had been carried out. The technical data for all the machines are given in the text under the illustration. Fig. 2 gives a view of the propulsion set proper, composed of the double helical gear, especially strongly dimensioned at the express desire of the owners, and of the two electric motors. Fig. 3 shows the engine room with a view of one of the two Diesel-dynamo sets. The experience gained by the firm over a period of many years, in the field of marine main and auxiliary drives as well as the latest regulations governing ship equipment were of course incorporated, in the design of all the electrical machinery and apparatus.

The control of the driving motors is carried out, in principle, in Ward-Leonard connection (Fig. 4). Each main dynamo with its electric motor forms a Leonard circuit. There are two potentiometers each having 30 positions to regulate the excitation of the main dynamos for each direction of travel; these are designed specially to this end and are particularly strongly built so as to be able to withstand the continuous manœuvring which is called for. Ordinary field rheostats are not suitable for this purpose.

The potentiometers, which are coupled together mechanically are, usually, operated from the bridge (see Fig. 31, page 13 of The Brown Boveri Review, January/February 1935). They can, however, be operated from the engine room (orders being transmitted by speaking tube or electric signals). Control from the bridge has given most satisfactory results on this vessel, which, as mentioned before, has to go through some difficult landing manœuvres. As the captain has the movements of the vessel in his own hands, the time required to carry out a given manœuvre is shortened and precision in manœuvring is increased. Further, less personel is required in the engine room as one machinist suffices to supervise the said room.

Of the two auxiliary 35-kW dynamos, one is required to excite the main dynamos and the other to supply lighting and the auxiliary power system of the ship. Either dynamo can be used as desired for one or the other purpose, a selecting switch being used for the change-over. On the main switchboard (Fig. 5) are mounted two Brown Boveri quick-acting regulators, a voltage regulator for whichever auxiliary dynamo is connected up to the light and auxiliary-power system (it holds the voltage across this system

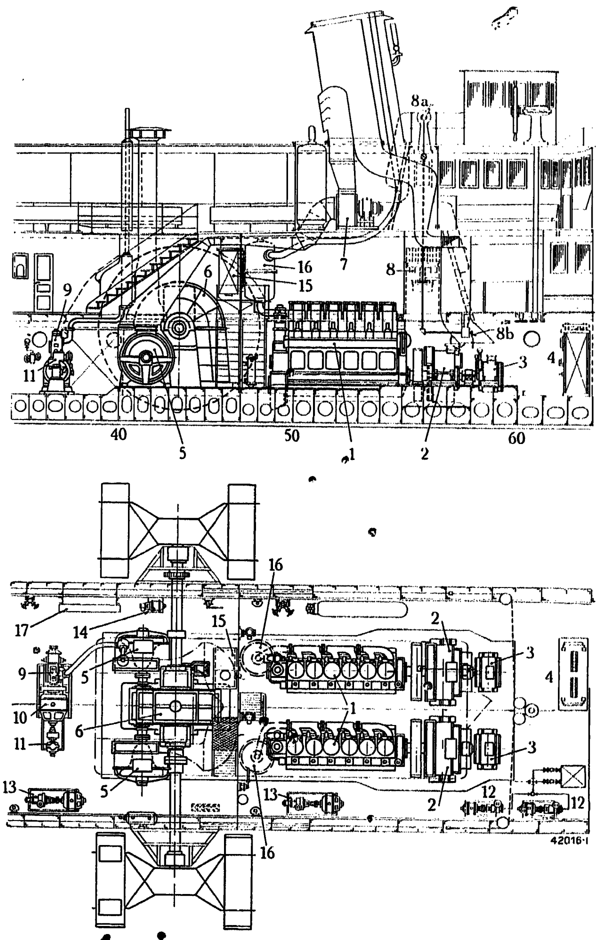


Fig. 1. — Layout of the Diesel-electric driving plant on the saloon paddle vessel "Genève".

1. Four-stroke cycle Diesel engines of Sulzer design, bore 290 mm, stroke 440 mm, each 535 B.H.P., 400 r.p.m.
2. Main dynamos, each 360 kW, 650 V.
3. Auxiliary and excitation dynamos each 35 kW, 65 V.
4. Main switchboard.
5. Electric motors for paddle-wheel drive each 460 H.P., 650 V, 500 r.p.m.
6. Reduction gear, ratio 1 to 10·5.
7. Suction fan of paddle-wheel motors.
8. Potentiometer.

8a. Control post and potentiometer drive on the bridge.

8b. Control post and potentiometer drive in engine room.

9. Auxiliary Diesel-engine 25 B.H.P., 550 r.p.m.
10. Auxiliary dynamo 16 kW, 65 V.
11. Auxiliary compressor.
12. Cooling water pump.
13. Bilge pump.
14. Fuel-oil transfer pump.
15. One-day tank for fuel.
16. Silencer.
17. Auxiliary switchboard.

[1] See The Brown Boveri Review, year 1925, No. 5 "The engines of the paddle tug-boat "Dordrecht".

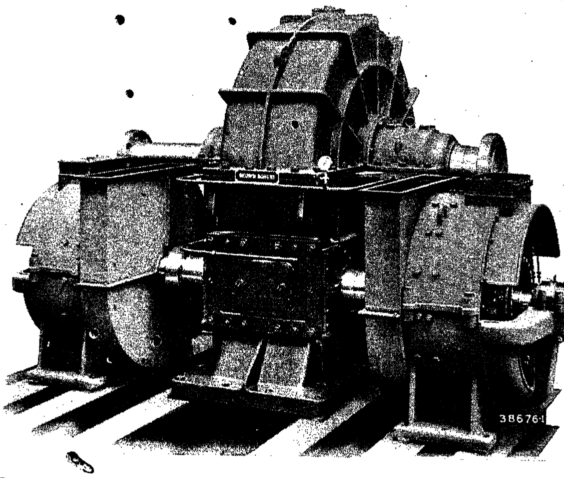


Fig. 2. — **Propulsion motors and reduction gears for the drive of the paddle-wheel shaft.**

Output of the motors	2 × 460	H.P.
Speed	500	r.p.m.
Speed of paddle-wheel shaft	47·5	r.p.m.
Pitch-circle diameter of big gear wheel	2222	mm
Ditto of pinion	210	mm
Width of teeth	2 × 280	mm

constant whatever the fluctuations in the speed of the Diesel-engines during difficult manœuvring may be) and a current-limiting regulator for whichever auxiliary dynamo is delivering excitation current for the main dynamos and the propulsion motors. The object of this excess-current regulator is to protect the main electric machines and, chiefly, the Diesel engines from undesirable overloading, which may be brought about by sudden manœuvring. Without a protective device of this kind, there is always the danger that the Diesel engines will be overloaded too greatly and even stalled when, for example, the paddle wheel or propeller shaft is reversed from full speed ahead to full speed astern or when the starting operation is carried out too suddenly. As the current regulator prevents the main current exceeding a certain maximum value dependent on the load and, thus, in a certain sense, limits the maximum loading of the Diesel engines, the danger described is eliminated. Fig. 6 shows clearly the effects of the current-limiting regulator. In practical operation, the control lever of the "Genève" can be *suddenly thrown over* from "Stop" to "Full speed ahead" or from the latter to "Full speed astern" without any danger that the current in the Ward Leonard circuit will exceed the admissible value or that the Diesel engines will be excessively overloaded.

The other protective devices are:—

(a) A thermal relay in each Ward-Leonard circuit. These relays are so adjusted that they will allow of at least eight complete landing manœuvres in succession before they act. When they do act, the excitation of the main dynamos and driving motors is cut out. If the relays act at a moment when the captain must have control over the movements of his vessel, he can switch in the excitation again independently by depressing a push-button placed on each control pillar.

(b) Each main dynamo is equipped with a counter-compound winding which acts in counter sense to overloads.

The "Genève" was put into service again at the beginning of September 1934. Although the power developed by the engines has been increased by one third, the new plant takes up about 4·85 m less total length, which saving in space was used to improve the passenger accommodation. With the present rated engine output of 1070 B.H.P. the speed of the vessel was increased from 13·5 to 14·75 knots and even to 15·75 knots with maximum load on the Diesel engine. At its former commercial speed, the vessel consumed per hour 686 kg of coal fuel and consumes, to-day, 138 kg of Diesel oil. Moreover, a saving of that quantity of fuel which used to be necessary for heating up the boilers and for keeping them under pressure is made, as well as a considerable reduction in the number of engine-room operatives.

Manœuvring times with the new electric plant are given herewith with the former times given in brackets.

(a) *Starting* from "Stop" to full paddle-wheel revolutions "ahead":— 80 (105) seconds.

(b) *Stopping* from full speed "ahead" (48·5 r.p.m.):— 10 (10) seconds until the paddle wheels are stopped.

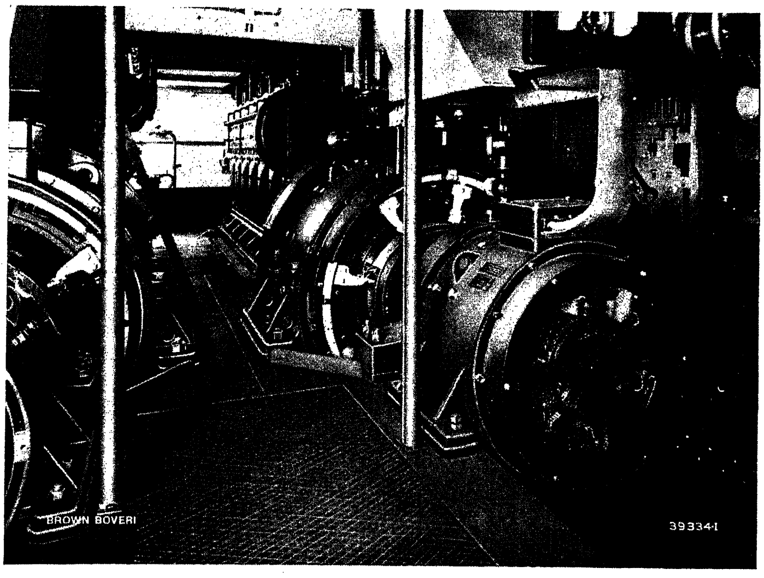
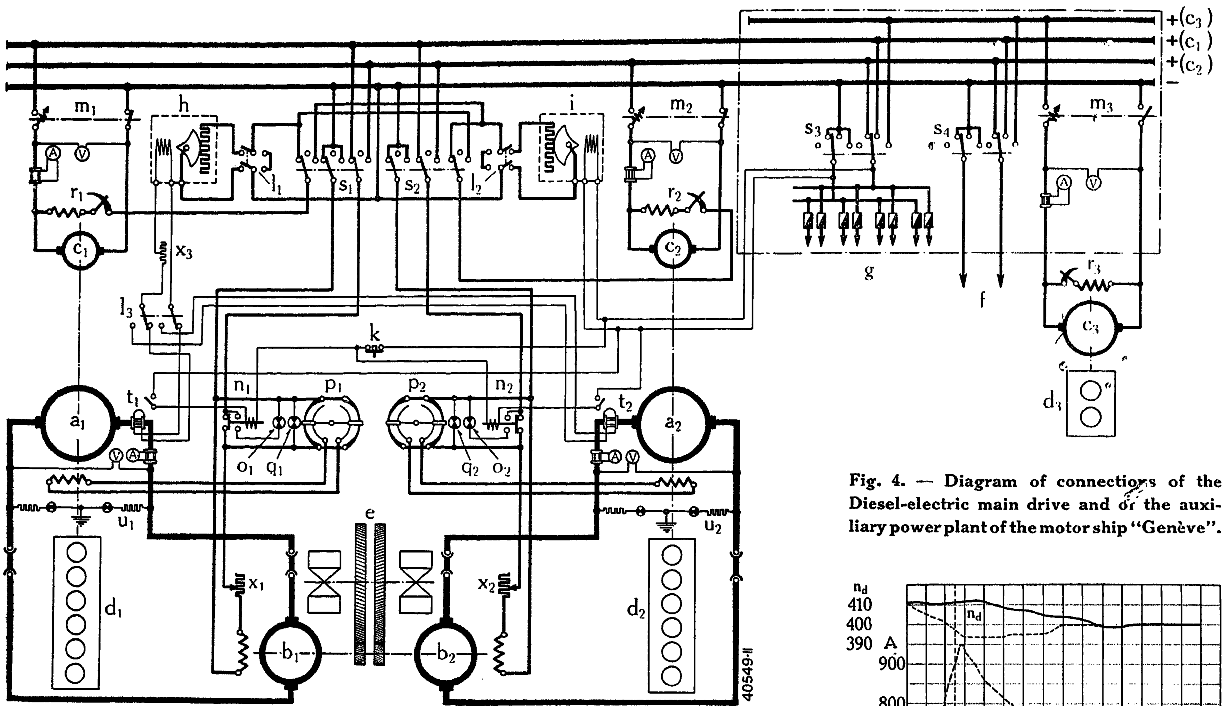


Fig. 3. — **View of the engine room of the M.S. "Genève" showing the two Diesel-engine sets.**



a_1. a_2. Main dynamos.
b_1. b_2. Propulsion motors.
c_1. c_2. Auxiliary dynamos, 35 kW.
c_3. Auxiliary dynamo, 16 kW.
d_1. d_2. Main Diesel engines.
d_3. Auxiliary Diesel engine.
e. Reduction gear and paddle wheels.
f. Branches for auxiliary power plant.
g. Branches for lighting.
h. Current-limiting regulator.
i. Voltage regulator.
k. Push-button switch.
l_1, l_2, l_3. Change-over switches.

m_1, m_2, m_3. Main circuit breakers with over-current trips.
n_1, n_2. Excitation contactors.
o_1, o_2, q_1, q_2. Pilot lamps.
p_1, p_2. Potentiometers.
r_1, r_2, r_3. Field rheostats.
s_1, s_2, s_3, s_4. Selecting switches.
t_1, t_2. Thermal over-current releases.
u_1, u_2. Electric leakage indicators.
x_1. x_2, x_3. Adjustable resistances.
A. Ammeter.
V. Voltmeter.

Fig. 4. — Diagram of connections of the Diesel-electric main drive and of the auxiliary power plant of the motor ship "Genève".

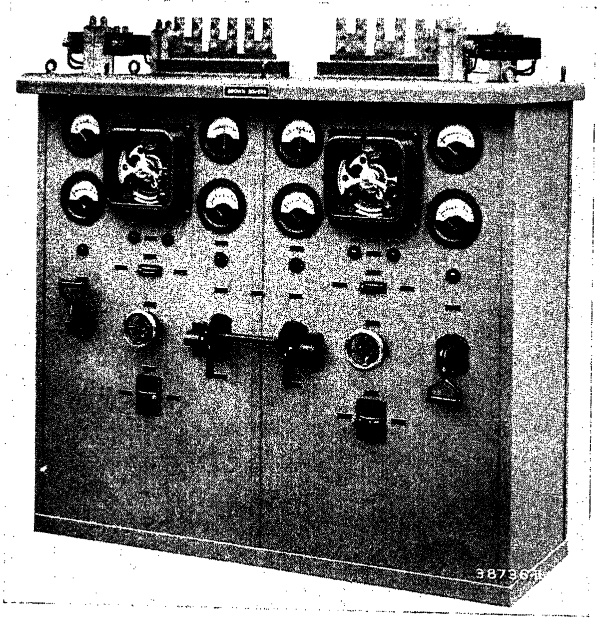


Fig. 5. — Main switchboard for the Diesel-electric driving plant of the M. S. "Genève".
***On the left,* the current-limiting regulator.**
***On the right,* the voltage regulator.**

35 (45) seconds until the vessel is motionless on a distance of 70 m.

(c) *Reversing* from full speed "ahead" (48·5 r. p. m.) to highest reverse paddle-wheel speed (40 r. p. m.):— 50 (60) seconds.

The overall efficiency of the electric transmission proved to be 83·5 %.

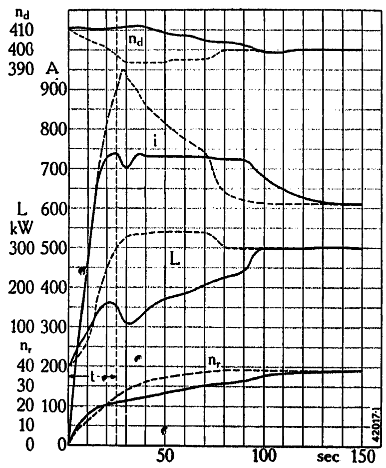


Fig. 6. — Effect of current-limiting regulator when the vessel starts by means of one Diesel-electric set.

———— with current-limiting regulator,
-------- without current-limiting regulator.

These curves do not represent the ordinary service conditions on the motor ship "Genève", but are only given to show the manner in which the current-limiting regulator acts. In the comparative test, only one Diesel set was used for propulsion and the potentiometer was so moved, with and without the current-limiting regulator, that it attained, in both cases, its end position in 25 seconds.

Readings were made, every 10 seconds, of the current, voltage and r. p. m. speed.

n_d. Speed of the Diesel engine (r. p. m.)
n_r. Speed of the paddle-wheel shaft (r. p. m.).
i. Main current in Ward-Leonard connection, in amperes.
L. Output of main dynamo, in kW.
t. Time for moving the potentiometer into the end position, in both tests = 25 sec.
sec. Time in seconds.

As regards vibration and noiselessness, the plant fulfilled every expectation and can be considered as a vindication as well as a classical example of the practicability of electric ship propulsion.

(MS 912) (To be continued.) *E. Klingelfuss. (Mo.)*

THE CONTROL OF THE VACUUM PUMP SET IN AUTOMATIC MUTATOR PLANTS.

Decimal index 621. 316. 264. 078.

THE February number, 1929, of The Brown Boveri Review contains a detailed description of the apparatus used for automatically-operated mutator plants. Brown Boveri has striven to develop this apparatus so as to render the operation of such stations as reliable as possible. With this end in view, the switchgear has been considerably modified and simplified, within the last years. At the present time, the following control apparatus (or control relays, as they are frequently termed) are used in automatic mutator stations, according to the conditions which have to be satisfied.

Control apparatus Type 9 f:— for an automatic mutator set with reclosing device.

Control apparatus Type 10 f:— for the reclosing of a feeder breaker.

Control apparatus Type 11 f:— for the reclosing of a feeder breaker with leakage test.

Control apparatus Type 12 b:— for the automatic operation of the vacuum pump set.

The principal part of each of these control apparatus is a servo-motor which drives a number of control and switching drums. The design of the servo-motor was improved, as compared to the earlier model, by mounting the current-carrying coils on a fixed magnetic core instead of having them oscillate with the armature. The armature which oscillates in the field of a permanent horse-shoe magnet carries no winding. The oscillations are due to the influence of an alternating field at right angles to the axis of the poles of the permanent magnet and of a spiral spring; these oscillations are in synchronism with the frequency of the alternating current producing the alternating field. Fig. 1 shows the servo-motor. The oscillations of the armature are transformed into a continuous rotary movement of the driving spindle of the apparatus, by means of an ingenious device formed by a ratchet along with a reduction gear.

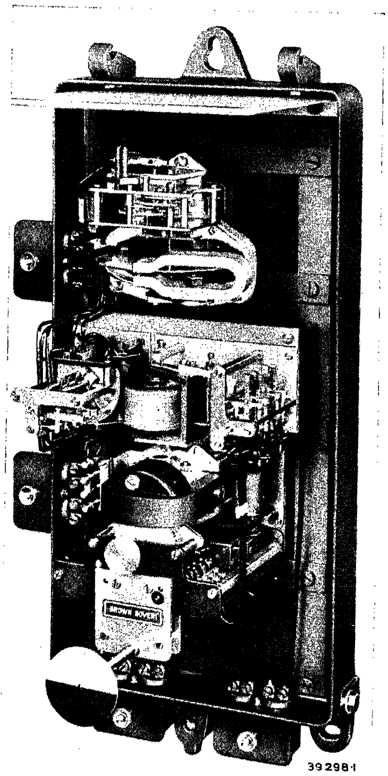


Fig. 1. — Control apparatus Type 12 b for the automatic control of a vacuum-pump set.

The arrangement of the control contacts, which cause the control apparatus to work, as well as of the switching contacts, which switch in and out driving motors of breakers or electro-magnetic drives, or the motors of the auxiliary services, etc. have been considerably improved as well. The experience gained in numerous plants was very useful here and the control apparatus, in its present form, is a very reliable apparatus indeed. All the other details of the control apparatus, such as auxiliary relays, timing mechanisms, etc., have been developed with a view to making them as reliable and as simple as possible.

The different Brown Boveri control apparatuses are specially designed and built according to the kind of station service they are required for. Thanks to the variety of types available, it is possible to eliminate the usual combinations of relays which, at the best, are complicated expedients. The stout construction and high adaptability of the control apparatus to the manifold exigencies of practical service allow of designing mutator stations which are both simple and very reliable in operation. This apparatus, which is working in many plants, to-day, has given an excellent account of itself and fulfilled all the requirements made of it.

In the following paragraphs, a summary description is given of the conditions of service and method of operation of control apparatus Type 12 b used for the automatic control of a vacuum pump set. The Review will publish, later, descriptions of other types of the control apparatus used in mutator plants. The duties to be fulfilled by control apparatus Type 12 b are the following:—

(a) The preliminary pump 3 in Fig. 2 should be switched in about 20 minutes after the high-vacuum pump 4, when the vacuum pump set is put to work for the first time or after being laid up for a long period. The high-vacuum pump is a static mercury-

vapour pump, so that a certain time elapses, after it has been connected to the supply system, before it develops its full volumetric output. This delay is set by a time mechanism built on the Ferraris principle (shown in diagram Fig. 1 above). Rotation in one sense is caused by the magnetic field and in counter-sense by a spring.

(b) The "in" and "out" signals of the vacuum galvanometer 6 are obeyed by the preliminary pump being put into service and cut out of service in function of the pressure inside the mutator. The high vacuum pump is continually removing the gas formed in the cylinder and compressing it in the space formed by the preliminary vacuum pipe.

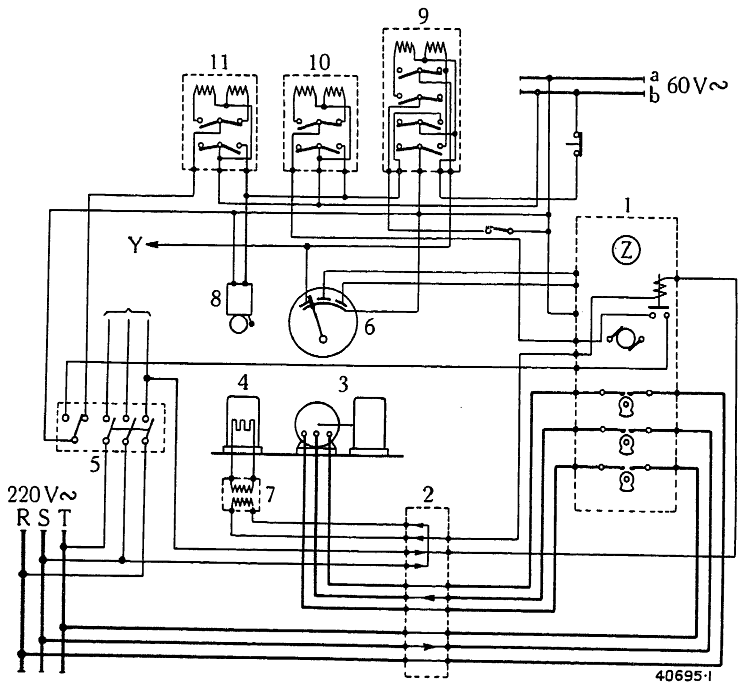


Fig. 2. — Fundamental diagram of connections of the equipment for automatic control of a vacuum-pump set.

1. Control apparatus Type 12.
2. Change-over switch.
3. Preliminary pump.
4. High-vacuum pump.
5. Switchbox.
6. Galvanometer.
7. Insulating transformer.
8. Bell.
9. Signalling apparatus.
10. Signalling apparatus.
11. Signalling apparatus.

(c) Upon failure of the current supply to the hot plate of the high-vacuum pump, the trouble is indicated by the current relay, lodged in the control apparatus, and by the signalling device 10. In this case the control apparatus is so governed by the current relay that it stops the preliminary pump. As soon as the hot-plate circuit is closed again, the current-relay is energized which puts the coil of the time mechanism under voltage. The time required to close the contact of the time mechanism is as long as the interruption of the current circuit of the relay coil, at the most 20 minutes, and it is only after this time has elapsed that the preliminary pump can be switched in again, if the pressure is too high.

(d) If switchbox 5 opens, the current supply to the hot plate is cut off. At the same time, the control apparatus switches out the preliminary pump (with the help of the current relay). This trouble is indicated by the signalling apparatus 11 actuated by an auxiliary contact of switchbox 5.

When the vacuum-pump set is started again, after trouble as specified under (c) and (d), the process is as explained under (a).

(e) When the pressure in the mutator or the temperature on the anode plate is too high, the mutator set is cut out and the trouble signalled back to the control room, through the agency of the control apparatus 9.

(f) If voltage across the hot-wire vacuum meter fails, the vacuum indicator of the galvanometer 6 takes up a position corresponding to a higher pressure in the mutator, which ordinarily would cause the mutator to be cut out. The blocking-current circuit must, therefore, be kept open, and this is done by means of a no-volt relay in the control apparatus. At the moment voltage comes back, the indicator goes back slowly to that position corresponding to the real pressure in the mutator. For this reason it is necessary that the blocking-current circuit should remain open for a certain time even after the voltage has picked up again, and this is attained with the help of the time mechanism already mentioned.

The change-over switch 2 allows of cutting out the control apparatus; on the other hand the vacuum-pump set can be governed by hand. To this end, the change-over switch is designed with four positions (out, high-vacuum pump in service, high and low vacuum —preliminary—pumps in service, automatic control). The different forms of trouble which may arise are indicated by signalling apparatus which were described in detail in the December number, 1929, of this Review. These signalling devices indicate immediately what the trouble is, further, the alarm device can be set free, immediately, so as to be available for signalling other trouble, this even if the first case signalled cannot be remedied at once.

(MS 916)

A. Greco. (Mo.)

DRUM-TYPE OR CAM-OPERATED CONTROLLERS FOR DRIVES WHICH DEMAND FREQUENT OPERATION?

Decimal index 621. 316. 542. 23.

FOR motors which have to be frequently started and the sense of rotation of which has to be changed, drum-type controllers, simply termed controllers, are generally used; besides these, cam-operated controllers with hammer contacts are utilized and, finally, contactor controls which have automatic starting gear actuated by push-button or by a master drum controller.

Contactor controls can generally be replaced by cam-operated controllers, for certain operating conditions such, for example, as those inherent to hoists and travelling gear and some auxiliary drives in rolling mills. Cam-operated controllers are designed for heavy outputs and frequent operation and are very easy to operate, thanks to the patented Brown Boveri design. As they are considerably cheaper than contactor controls, they are used, wherever possible, for drives of the types mentioned. Of course, there will always be drives for which contactor control will be given preference, on account of certain special conditions to be fulfilled, such, for example as particular starting conditions (control by accelerating relay or automatic control, etc.).

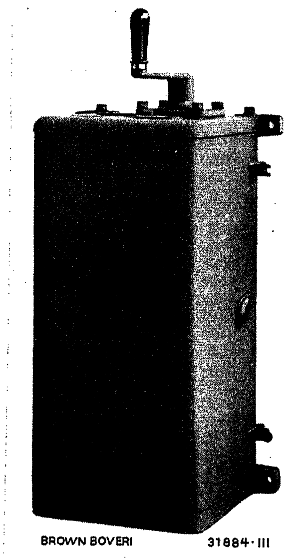


Fig. 1. — Drum controller, Type T, with crank drive.

Drum-type controllers are delivered for use with three-phase A. C. motors for outputs up to 110 kW and for a frequency of operation of up to 120 per hour. They are used for switching in and out of service and for speed regulation (Fig. 1).

These controllers meet in the most satisfactory manner all the requirements of standard hoisting and travelling plant service, namely stout construction combined to relatively light weight, compact design and great accessibility. The drum-type controller consists of the housing with sheet-metal walls and of the built-in switching gear, of which the main parts are a row of contact fingers and the drum itself.

It is essential that the contact fingers should fulfil the special requirements of apparatus subjected to such heavy duty, namely:—

Easy replacement of the arcing contacts in as short a time as possible.

Perfect alignment of the contact finger.

Straight design of the finger arm in order to reduce to a minimum the danger of jamming when the drum is rotated.

The drum controllers can be equipped with various types of drive, namely with a handwheel or a crank or else with the well-known lever arrangement which allows of controlling one or other of two controllers as desired by means of a single lever (Fig. 2).

As mentioned before, the drum-type controllers just described can be used for a maximum of 120 operations per hour.

The *cam-operated controllers* are used for more frequent switching operations, being able to handle up to 600 switching operations per hour. These controllers are built for a maximum output of 195 kW and have many qualities lacking in contactor equipments and drum-type controllers. The cam-operated controller is easily mounted owing to the compactness of the design and it allows of one driver operating several controllers at once or in succession thanks to the facility of control, this without overstrain. This simultaneous operation of several controllers is used on loading bridges and similar hoisting appliances, for example, in which the various crane movements such as hoisting, crab traversing, luffing, etc., although initiated in succession, are carried out with a certain overlap. Although the drive of the cam-operated controller is easy to move, from one position to the next, the design is such that each position, as it is reached, is distinctly felt by the operator. This latter result was attained by fitting all friction parts with ball bearings and applying a patented Brown Boveri compensating device.

The cam-operated controller is distinguished from the drum controller chiefly by the different design of the drum. Instead of the drum having copper segments screwed on to cast iron, which establish different connections between fixed contact fingers, there are a number of disc-shaped cams mounted on the main shaft and made of very resistant insulating material. Each of these discs operates a hammer switch fitted with its own arc blow out, a removable arcing chamber and rugged block contacts. The hammer switch is maintained in the closed position by spring pressure. The separate arc blow out of each switch element allows of cutting out the heaviest loads and reducing to a minimum the damage by burns to the

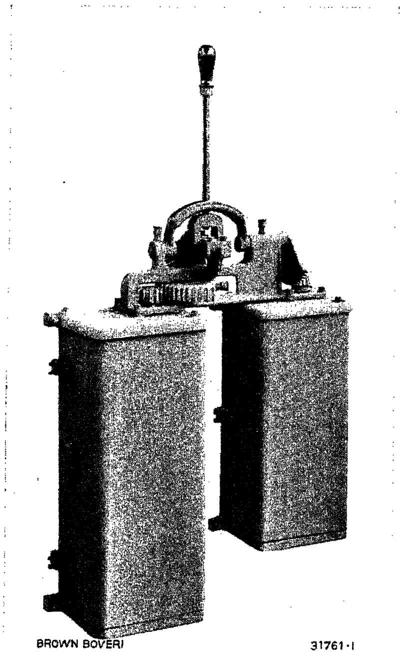


Fig. 2. — Drum controller, Type T, with universal drive by vertical lever.

contacts. Fig. 3 shows a cam-operated controller, from which the sheet metal covering has been removed. The cam-operated controller is provided with either handwheel or crank, as is the case for the drum-type controller, different types of lever control can also be used, on request.

The *drum-type controller* is very suitable for ordinary reversing connections where the switching process is identical on both sides, that is to say it is suitable for drives in which the motor must work as such in both senses of rotation and where generative work and electric braking work is eliminated. In starting controllers, that is to say those for a single sense of motor rotation, the connections are such that if the drum is rotated in the wrong sense the circuit of the current is not closed.

Although the simple reversing connection was universally used formerly, both for hoisting and for travelling gear, the use of electric braking connections is becoming more frequent from year to year. Electric braking is especially desirable on hoisting gear. With three-phase A. C. motors, the drum-type controllers can be used for electric braking of a load being lowered, by allowing the said load to bring the motor up to a speed slightly above that of synchronism. There is, however, no possibility of load lowering at a speed below synchronism or of regulation below that speed.

Cam-operated controllers, on the contrary, are suitable both for ordinary reversing connections and, very particularly, for special connections such as braking connections etc. The cam discs operating the contacts allow of making any connections desired; all that is necessary is to design the cam discs in such a way that they produce the desired connections at the proper moment. All the special connections which are used for hoisting gears as well as travelling gears, for which also speed regulation below synchronism is desirable during the electric braking, can be effected by means of the cam-operated controllers.

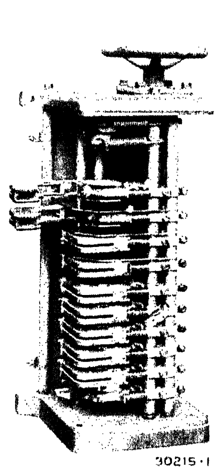


Fig. 3. — Cam-operated controller, Type UN, with handwheel drive, casing removed.

In *drum-type controllers* the arcing contacts on the fingers as well as the arcing points on the drum must be cleaned and put in order, from time to time, a duty which is not called for with a cam-operated controller.

The *cam-operated controllers* can be maintained in service over a longer period of time, without supervision. Experience shows that even in hard, non-stop, 24-hours service and about 400 operations to the hour, it is only necessary to change a few contact blocks after from three to four months of operation. It should be especially mentioned that no attendance of the controller is called for during the period in question which is prolonged to from six to eight months when only twelve-hour service is required. This will often be the deciding factor in choosing between cam-operated or drum-operated controllers.

(MS 914) *E. Altschul. (Mo.)*

NOTES.

Results of motor-coach service on the electrified St. Gall-Gais-Appenzell Railway.

Decimal index 621. 335. 4 (494).

THE former Appenzell tramway service with a mixed adhesion and rack-operated system was converted from steam to electric traction (D. C. 1500 V) in the spring of the year 1931.[1] Service is carried out by five motor coaches, of which the electrical equipment was supplied by Brown Boveri and the mechanical parts by the Swiss Locomotive and Machine Works, Winterthur, as general contractors and the Schweizerische Industrie-Gesellschaft, Neuhausen. Now that these motor coaches have been in continuous service for several years, it may be of interest to publish some data on the results attained with the electrical equipment in question.

It should be mentioned, first, that the one-hour rating of 520 H.P. specified for originally was increased to 570 H.P., as a result of the excellent test results, when the coaches

[1] See The Brown Boveri Review, year 1930, No. 9, page 294 and The Schweizerische Bauzeitung year 1932, Vol. 100, No. 21.

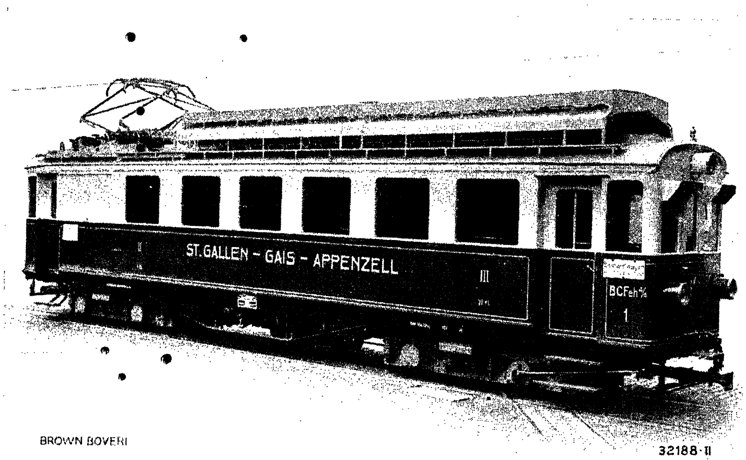


Fig. 1. — **View of motor coach ready for service.**

were taken over, the speed corresponding thereto being 17·8 km/h and the tractive effort about 8600 kg, at the wheel tread. This allowed of increasing the maximum train weight for trains running over the whole length of line, from 110 t to 120 t. The dead weight of the coach is 39·4 t of which about 8·7 t are for the electrical equipment, which is very little with regard to the power developed by the coach. The five motor coaches together have covered about 1,000,000 line kilometers, a result which is all the more remarkable, as the useful single length of the line is only 19·45 km, and this includes five sections which have to be rack-operated.

The drive of the two bogies of each coach is by two D. C. series-wound motors connected in series to each other suspended under the body of the coach. The torque of each motor is transmitted to the two adhesion wheels as well as to the driving rack wheels on the bogie through a slip coupling and a first spur-wheel gear to a cardan shaft with axis parallel to the coach axis and then through a second and third reduction gear having bevel and spur wheels. This novel solution of the driving problem has proved most suitable for the conditions to be met and is, indeed, up to date, the only solution allowing of lodging the relatively high motor power in the coach in such a way as to satisfy the very difficult service conditions imposed by this line.

The electric equipment has given an excellent account of itself, in every respect. The traction motors are in first-rate condition to-day, the commutators are clean and show hardly a sign of wear. The stout design and excellent commutating conditions allow of considerable overloading of the motors which in turn allows of surmounting the requirements of peak traffic conditions. The use of four economic regulating steps which can be carried out with the motors connected in one way, a result attained by strengthening and weakening the field, allows of most satisfactory adjustment to the particular requirements of the railway. The control of the regulating apparatus is easy and does much to simplify the attendance, thus giving the driver time to watch the track which has many curves and fol-

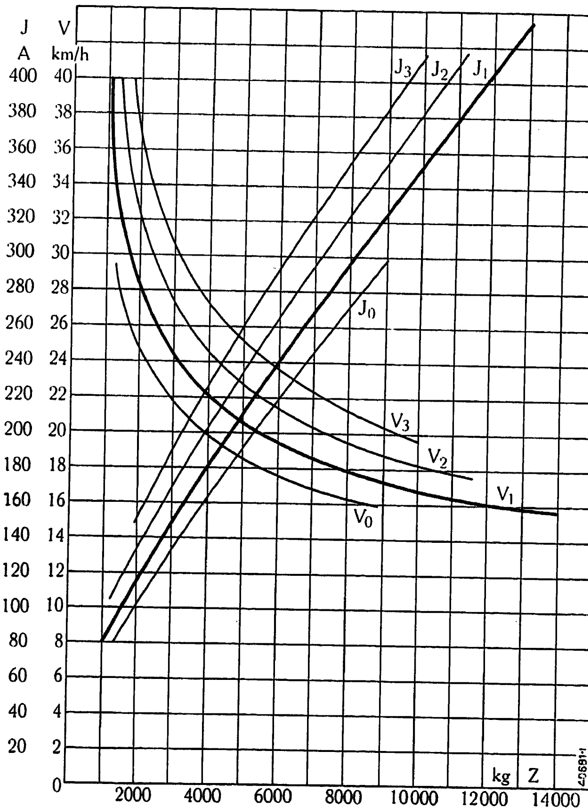


Fig. 2. — **Characteristic curves of motor coach.**
v. Travelling speed in km/h. J. Current in A taken by coach.

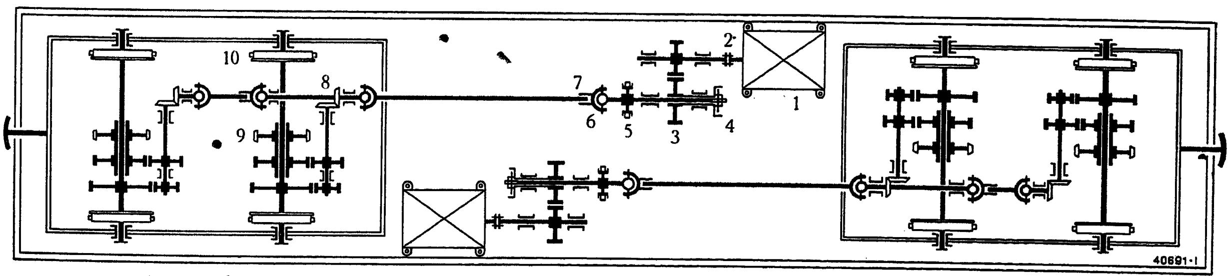


Fig. 3. — **Diagrammatic arrangement of the drive of a motor coach for mixed adhesion and rack operation.**

1. D. C. series motor.
2. Flexible coupling.
3. Spur-gear wheels of reduction gear.
4. Slip coupling.
5. Emergency brake for hand operation only.
6. Cardan joint.
7. Sliding coupling.
8. Bevel gear.
9. Driving gear-wheel.
10. Adhesion driving wheel with hand and pneumatically-operated block brake.

lows the main road. As to the state of apparatus itself, such as controllers, resistances, main circuit breakers and current collectors, everything was found to be in perfect order. The current collector is designed for two bows. The railway puts on winter bows with copper contact pieces for the winter service, while ordinary bows with aluminium contact pieces are used at other seasons, the results attained being very satisfactory. The railway authorities have reason to be very satisfied that the upkeep costs of the electric equipment should have turned out to be well below expectations, while the consumption of replacement parts is very low. It must be admitted that a considerable part of the credit for this is due to the careful attendance and supervision of equipment exercised by the personel of the railway. There is no reason why these motor coaches should not be able to maintain service for many years to come and continue to give as great satisfaction as heretofore.

(MS 910) *E. Hugentobler. (Mo.)*

The electric drive of rotary presses by means of three-phase shunt commutator motors.

Decimal index 621.34:655.31.

ALL daily and weekly newspapers and illustrated magazines, of every variety, are printed on rotary presses, exclusively. Each part of these machines has been improved, in recent years, in order to bring the working speed of the rotary press up to that demanded of modern machinery. The printing speed proper has been constantly increased, so that 20 to 25,000 revolutions of the printing cylinder in one hour is no longer exceptional in rotary presses for newsprint. At the same time, the quality of the print itself was improved while attendance was simplified. As an example, mention may be made of the automatic regulation of the paper tension, the changing of rollers at reduced speeds and of the automatic raising and setting of the counter-pressure cylinder in non-relief printing machines and in offset machines, problems which could only be solved, in so satisfactory or so simple a manner, with the aid of electric drives and controls.

Only motors which fulfil all service requirements in every respect can be used to drive these modern and powerful rotary presses. The requirements in question can be summarized as follows:— The printing speed must be variable within a wide range, according to the colour, quality of paper and type, this range being at least 1 to 3. Speed variation must be very gradual because if this condition is not fulfilled the paper is very apt to tear, a most undesirable contingency which means loss of material and of time and may even cause harm to the machine when high speeds are in question. In order that the paper should not already tear at starting, the start must be smooth and gradual. Further, the printing speed desired should not vary even if the load changes which is very important in machines with printing units which can be switched in and out, according to requirements. The drives must be able to run alone or in parallel in the case of double or multiple rotary presses the different units of which can be driven separately or coupled together. Further, control of the drives is called for from several points on the machine and in as simple a manner as possible, also, the said drives must always be ready for service and work economically and reliably, while taking up little space.

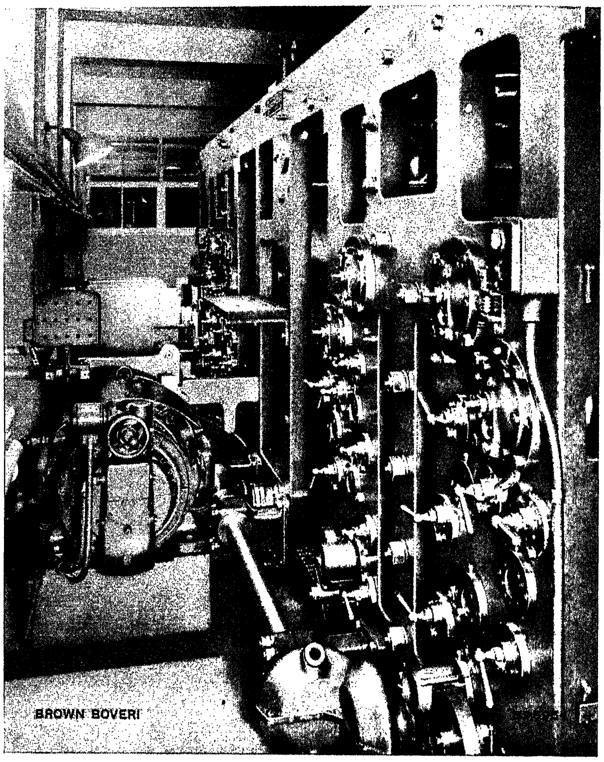


Fig. 1. — Rotary press for newsprint driven by a 26 kW three-phase shunt commutator motor, with automatic push-button control, speed range 1 to 5.

Drives by three-phase shunt commutator motors fulfil all these requirements admirably. Recognizing the great advantages offered by these motors, Brown Boveri has developed drives for rotary presses by shunt commutator motors which have given every satisfaction in service.

These motors are characterized, by the wide range of absolutely smooth speed variation, without any losses. The range of speed variation can be chosen at will, according to the conditions of service to be met; as a rule a range of 1 to 4 up to 1 to 5 suffices. The speed does not vary, thanks to their shunt characteristic even under big load changes, such as occur on machines with several printing units which can be coupled as required. Starting is absolutely smooth within the speed ranges mentioned. Starting and speed regulation is carried out by simply displacing the brushes which allows of increasing the speed gradually and smoothly up to the working speed called for. Another advantage is that the three-phase shunt commutator motor practically conserves the same excellent efficiency over the major part of the speed range. As rotary presses run at their highest speeds very rarely, although the drives must allow of the said speeds being attained, it will be clear that the three-phase shunt commutator

motor is, economically, far superior to the three-phase induction motor the speed of which can only be regulated in steps and at the cost of considerably loss of power in rheostats and which also varies considerably with the load. The higher cost of purchase of the three-phase shunt commutator motor as compared to the three-phase induction motor is very quickly balanced by the saving in power consumption of the former. This great suitability of the three-phase shunt commutator motor for the drive of rotary presses is still further enhanced by the push-button control system developed by Brown Boveri which is both simple and very suitable to the object for which it is designed. Operation is made certain and easy by this method of control.

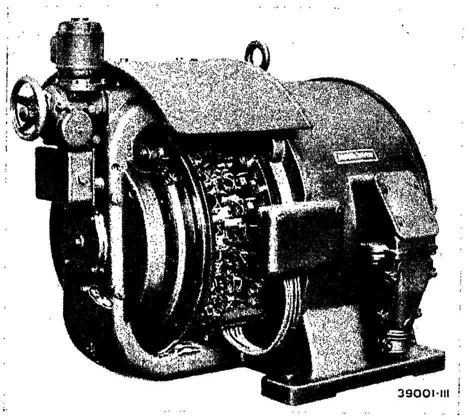


Fig. 2. — 37 kW, three-phase shunt commutator motor with built-on brush displacement motor and end-travel switch.

Mention must also be made of a special regulating system developed by Brown Boveri for the drive of double and multiple rotary presses by three-phase shunt commutator motors which system allows of even load distribution on all the motors, thus preventing the overloading of certain units.

(MS 917) *A. Auer. (Mo.)*

Double motors for driving wood-working machines.

Decimal index 621.34:674.05.

Wood planers and cutters work at very high cutting speeds and require correspondingly high speeds of the driving shafts. With machines which are direct driven by three-phase induction motors, special measures must be taken in order to reach speeds of over 3000 r. p. m. In this case, either motors for higher frequencies — attained through the agency of a frequency converter — or else double motors, which do not require any frequency converter, are utilized. Generally speaking, motors for high frequencies are possible for one single speed alone, if simple design is to be adhered to. Double motors, on the contrary, can be built for two or three speeds and are cheaper than a plant comprising a driving motor and frequency changer.

The working principle of the double motor is the following:—

Two motors are concentrically mounted in a common housing. The rotor of the outer motor carries the stator of the inner motor. If this stator is wound for two poles and if it rotates at about 3000 r. p. m., the field it produces rotates at about 6000 r. p. m., while, if the same stator rotates at about 1500 r. p. m., the rotating field attains about 4500 r. p. m. The speed of the rotor of the inner motor is thus about 6000 r. p. m. in one case and about 4500 in the other. If the double motor is called on to rotate at about 3000 r. p. m., the inner motor alone is connected to the supply and its stator must be prevented from rotating.

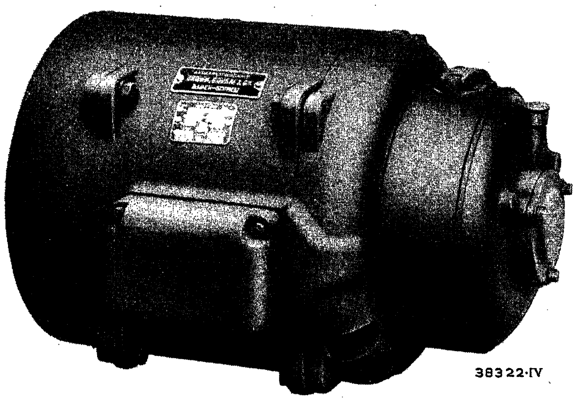


Fig. 1. — Motor for a planer, Type KH 72/4 (with shield for securing the motor in position), 4·5 kW, about 4500 r. p. m., 50 cycles.

For driving planers, double motors for one speed only are used, which rotate at about 4500 or 6000 r. p. m. (Fig. 1). The rotor of the inner motor is mounted on an extension of the shaft of the planer-iron. The motor housing is built on to the frame of the machine being driven and, frequently, it is found more practical to secure the motor through the agency of a special shield. The starting of these motors for only one speed is a very simple matter, the stator of the inner motor does not require to be blocked.

Double motors with two, but, mostly, with three speeds are used for moulding machines and cutting machines (Fig. 2). Slide rails cast on to the housing of the motor facilitate building it on and displacing it in the frame of the moulding machine proper. The motor shaft is also the working

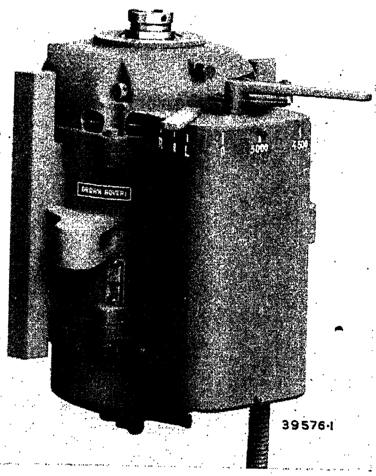


Fig. 2. — Motor for a moulding machine Type KD 62/346, 3 kW, about 3000/4500/6000 r. p. m., 50 cycles.

shaft, in this case. The main control switch is built on to the motor. This control switch of the drum type is so connected to the blocking device of the inner motor and to the sense-of-rotation switch as well as to a special stop device — of which more will be said later — that all switching processes must take place in their proper sequence.

In the neutral position and in the 3000 r. p. m. position, in which only the inner motor is connected up to the system, the stator of the said motor is prevented from rotating by a block brake actuated by the switch drum. If the switch drum is rotated further into the 4500 r. p. m. position, the brake is first made to open, only after which the switch establishes the connections of the outer motor to the system. In the last position of the switch, for 6000 r. p. m., the stator winding of the outer motor is switched over from four to two poles. The main switch drum has a special braking position in which the inner motor is fed by counter current. If the switch lever is left free the switch drum rotates back automatically from the braking into the neutral position. There is a simple, patented, stop device combined with the block brake which prevents switching to the speed of about 4500 and 6000 r. p. m. when a slot cutter, which can only be allowed to rotate at about 3000 r. p. m., is on the shaft. If an attempt is made to rotate the switch into the position corresponding to about 4500 r. p. m., a lever comes up against a collar on the slot cutter and prevents the drum being rotated further. The drum is only free to be switched round further after the slot cutter has been taken off the shaft and when tools without the collar are mounted on the shaft. The sense of rotation of the motor is set by means of a second switch drum interlocked with the main switch drum in such a way that a change in the sense of rotation can only be carried out when the main drum is in the neutral position, that is to say when the motor is cut out.

The motors are so designed that they can be taken apart and put together again easily, no specially trained man being required for this. Although the slip rings are totally enclosed, the brushes are easily reached by raising a cover. Further, the connections of the stator winding of the inner motor to the slip rings are easy to supervise and simple to connect up, which is a point of importance when it is necessary to dismantle the motor. The connecting up of the moulding-machine motor to the system is a simple matter, all that is necessary is to secure the leads of the three phases to the terminals of the control switch. All inner connections between motor and switch are already made.

Thanks to their reliability and simple attendance requirements, the double motors described can be confided to any workman and they fulfil every condition required of machine-tool motors for wood working.

(MS 919) *M. Fitz. (Mo.)*

The motor coaches of the Sassi-Superga electric rack railway (Italy).

Decimal index 621.335.4 (45).

THIS mountain railway near Turin which, up till lately, was operated, on the Agudio system, as a combined rope and rack line, was transformed into a purely rack railway equipped with Strub rack, at the beginning of 1935. Traffic conditions were considerably improved, thereby, and the carrying capacity of the line, which was taken over and operated by the Turin Tramways, was increased both by the acquisition of two four-axle and one two-axle electric motor coaches and by speeding up the coaches. Tecnomasio Brown Boveri Milan delivered the electrical equipment of these motor coaches, including the driving gear for meshing with the rack, while the Savigliano Machine Works at Turin delivered the mechanical parts of the coaches.

The main characterisitics of this railway are tabulated, herewith:

Length of the line section	3·125 km
Difference of level between stations	420 m
Steepest gradient	20·5 %
Gauge	1445 mm
Radius of sharpest curve	300 m
Current system	D. C.
Operating voltage, at supply point	600 V
Highest travelling speed	13·5 km/h

The weight of the four-axle motor coaches empty (tare) is 26·2 t each and they can carry 70 passengers. The heaviest train weight to be drawn, composed of a four-axle motor coach and two trailers is about 58·2 t, including passengers. The tare of the two-axle motor coach is 16·65 t and it is designed to carry 40 passengers. The heaviest train weight to be drawn, in this case, consisting of a motor coach and one trailer amounts to about 33 t, including passengers. The times recorded during the trial runs for travelling over the whole line section without a stop were

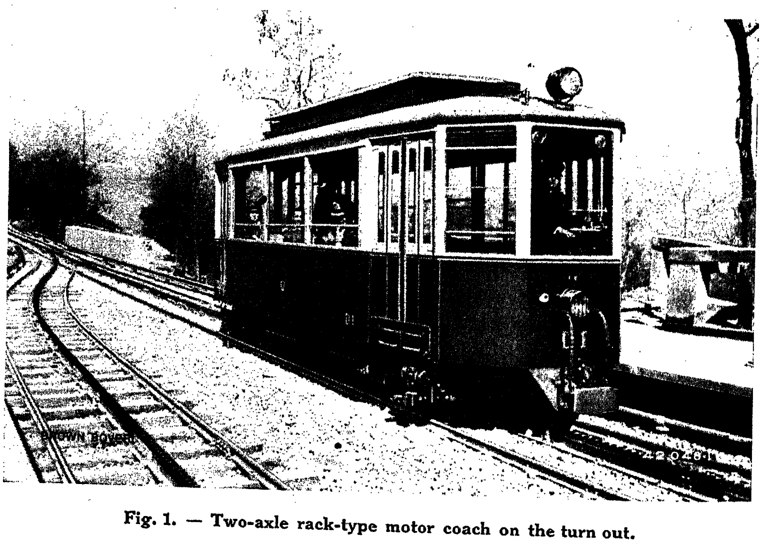


Fig. 1. — Two-axle rack-type motor coach on the turn out.

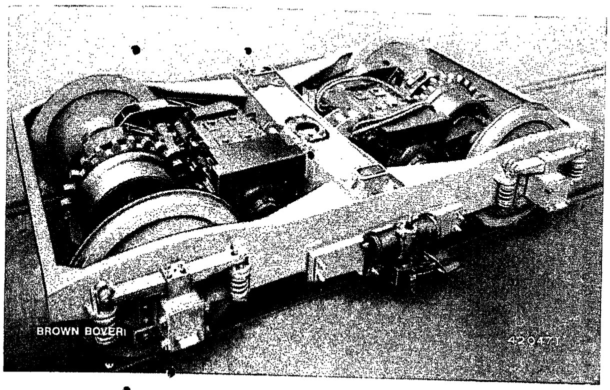


Fig. 2. — Bogie of the four-axle motor coach with built-on driving motors.

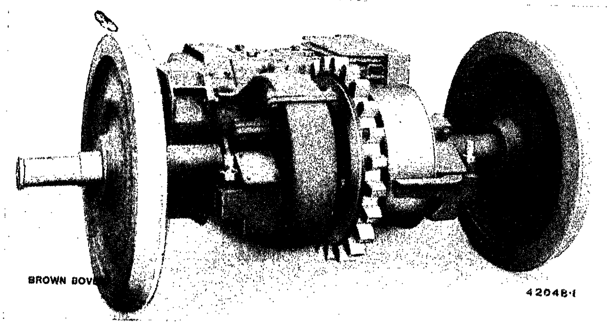


Fig. 3. — Wheel set with built-in driving motor and driving gear.

using resistance braking on the down grade is carried out by a controller in the driver's cab, having ten starting, ten braking and two field-weakening positions for the up-grade run. In the four-axle coaches each set of two motors can be cut out independently in order to make it possible to travel back, in an emergency, to the depot beside the lower station, with only one motor set running, using electric braking. Starting and braking resistances are formed of frames carrying chronin ribbon placed on the roof, for natural cooling.

The braking equipment comprises two hand-operated band brakes, independent of each other, besides the electric service brake. These hand brakes act on all the driving cog wheels of the coach, simultaneously. One of these brakes is also combined with an automatic compressed-air Westinghouse train-braking device. Further, there is the automatically operated over-speed brake, usually fitted on mountain railways, which causes the compressed-air brake device to act when the highest admissible speed has been exceeded by about 10 %; this stops the train automatically. As the motor coaches are generally run by one man, the well-known Brown Boveri safety device is used which causes the train to stop immediately, in the same manner as the over-speed brake, if the driver looses consciousness. The compressed air for train braking, acoustic signalling devices and pneumatic control of the rail-current collec-

16—18 minutes according to the load, for trains on the up-grade or the down-grade, this with the train loads just given and at voltages of 470—610 V. During week days and when traffic is light, service is kept up by the two-axle motor coach alone while on Sundays and on holidays the two four-axle coaches run simultaneously, in counter sense, which is made possible by a turn out in the middle of the line section.

Current is supplied from the lower station through a third rail placed on one side. The four-axle motor coaches have four self-ventilated series-wound motors each of 103 H.P. one-hour rating at a travelling speed of 10·3 km/h and 550/2 V terminal voltage. The two-axle coach is equipped with two motors, instead of four, of the same type. For the sake of simplicity, two motors are always connected up in series, as a series-parallel connection of the two motors offers no particular advantage under the service conditions pertaining. There is, therefore, always series-parallel connection of all the four motors, in the case of the four-axle motor coaches. The motors are of the nose-suspended type and work on the driving cog wheel through a double reduction gear giving a total ratio of 1 to 18. The driving cog wheel has a pitch-circle diameter of 644 mm. Starting the motor coaches and regulating their speed when

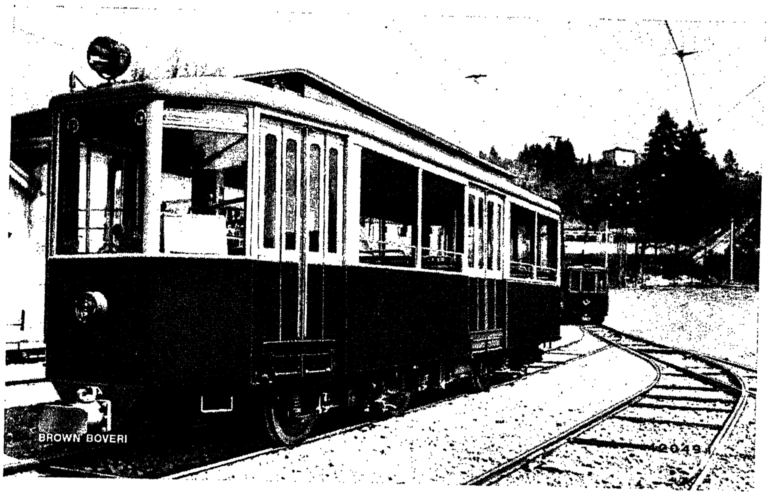


Fig. 4. — Four-axle rack-type motor coach.
The coach is on the lines of the Turin tramway system before being run over to the rack-line section.

tors is delivered by a Brown Boveri reciprocating compressor of the latest type, delivering 200 litres of air per minute at a gauge pressure of 6 kg/cm².

Very severe taking-over tests were carried out on the motor coaches just described and these gave the clients and the authorities entire satisfaction. Service with the newly transformed line was taken up in the middle of April 1935.

(MS 925) *E. Hugentobler. (Mo.)*

A new type of circuit breaker for D. C. motor vehicles.

Decimal index 621. 316. 57. 064. 24.

A new type of high-power circuit breaker has been brought out, which forms a very efficient protection against overloads for the electrical equipment of motor vehicles.

During recent years, the commercial speeds demanded of motor vehicles have been constantly rising and this calls for a corresponding increase in the power developed by the said vehicles. The types of circuit breaker available up till now were barely able to handle the heavy rupturing currents corresponding to these heavier outputs and a demand arose for a type of circuit breaker of greater capacity. In response to this, Brown Boveri have now developed a new type of circuit breaker chiefly intended for tramway coaches and for the smaller motor coaches used on secondary lines. This circuit breaker, designed for 750 V and 250 A one-hour rating, is shown in Fig. 1, without its casing.

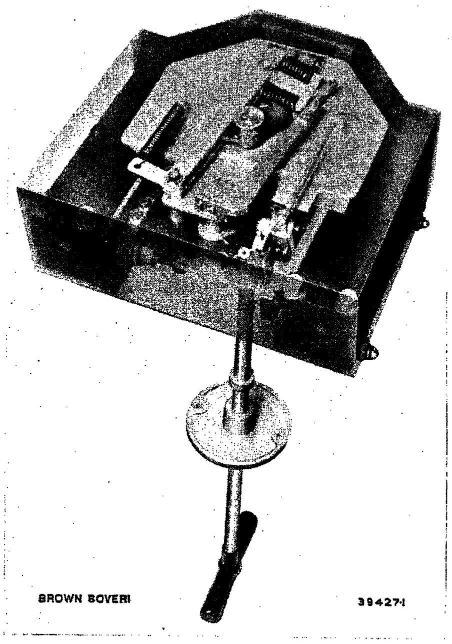


Fig. 1. — Circuit breaker Type F4gl for 250 A one-hour rating, with shield outlined.

The leading principle in the design is simplicity and compactness combined with high rupturing capacity. The principles followed by Brown Boveri when designing high-voltage breakers are also adhered to, in the present case. The blow-out coil also acts as magnet coil for the tripping mechanism and this made the design simpler.

The essential parts of the apparatus are the two contact horns with changeable hammer-type contacts, the combined blow-out and tripping coil, the mechanism for over-current tripping, the arcing chamber, the insulated handle with flexible insulating coupling, the position-indicating dial and the sheet-metal shield.

The strength of the tripping current can be set at any value desired between 200 A and 600 A. Numerous tests carried out on the test bed show that the maximum value of the rupturing current which can be handled with perfect reliablity at 750 V is:—

5500 A under non-inductive load and
4000 A under a load having an inductance of 4 mH.

It was further proved that the breaker could be used for voltages up to 1000 V, without any trouble, under which conditions the following rupturing currents can be safely handled.

4500 A under non-inductive load and
3500 A under a load having an inductance of 4 mH.

Figs. 2 and 3 show a rupturing process under inductive and non-inductive load.

The inductance of 4 mH, indicated above, corresponds approximately to that of a single tramway line trolley wire of about 3 kilometers length.

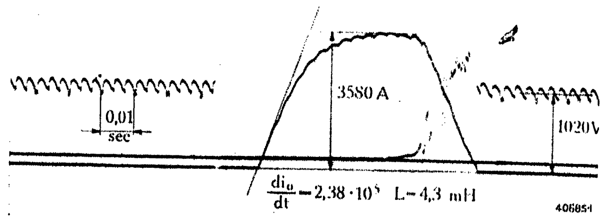


Fig. 2. — Rupturing process during a short circuit on a D. C. circuit (inductive load).

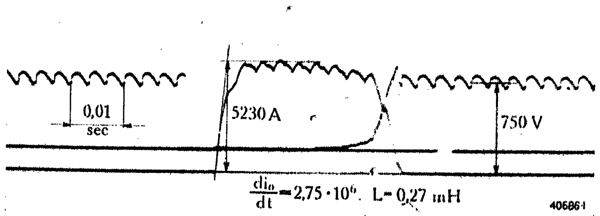


Fig. 3. — Rupturing process during a short circuit on a D. C. circuit (non-inductive load).

Short-circuit currents which result from a short circuit occurring on a vehicle at some distance from the substation are damped down by the resistance of the trolley wire and the feeder cable and can be handled by the new breaker without any trouble at all.

A special tripping characteristic of this breaker (retarded tripping time) allows of heavy short circuits, which occur quite close to the substation being cleared by the feeder breaker. This is a valuable quality as it allows of small overall dimensions and light weight for the breakers to be lodged in motor vehicles and makes them easy to operate.

The new type of circuit breaker meets every requirement of modern tramway-line service and is certainly the most efficient design to be found on the market, to-day. Despite its big rupturing capacity, it is very compact and only weighs 20 kg including shield and handle.

(MS 906) *O. Gysin. (Mo.)*

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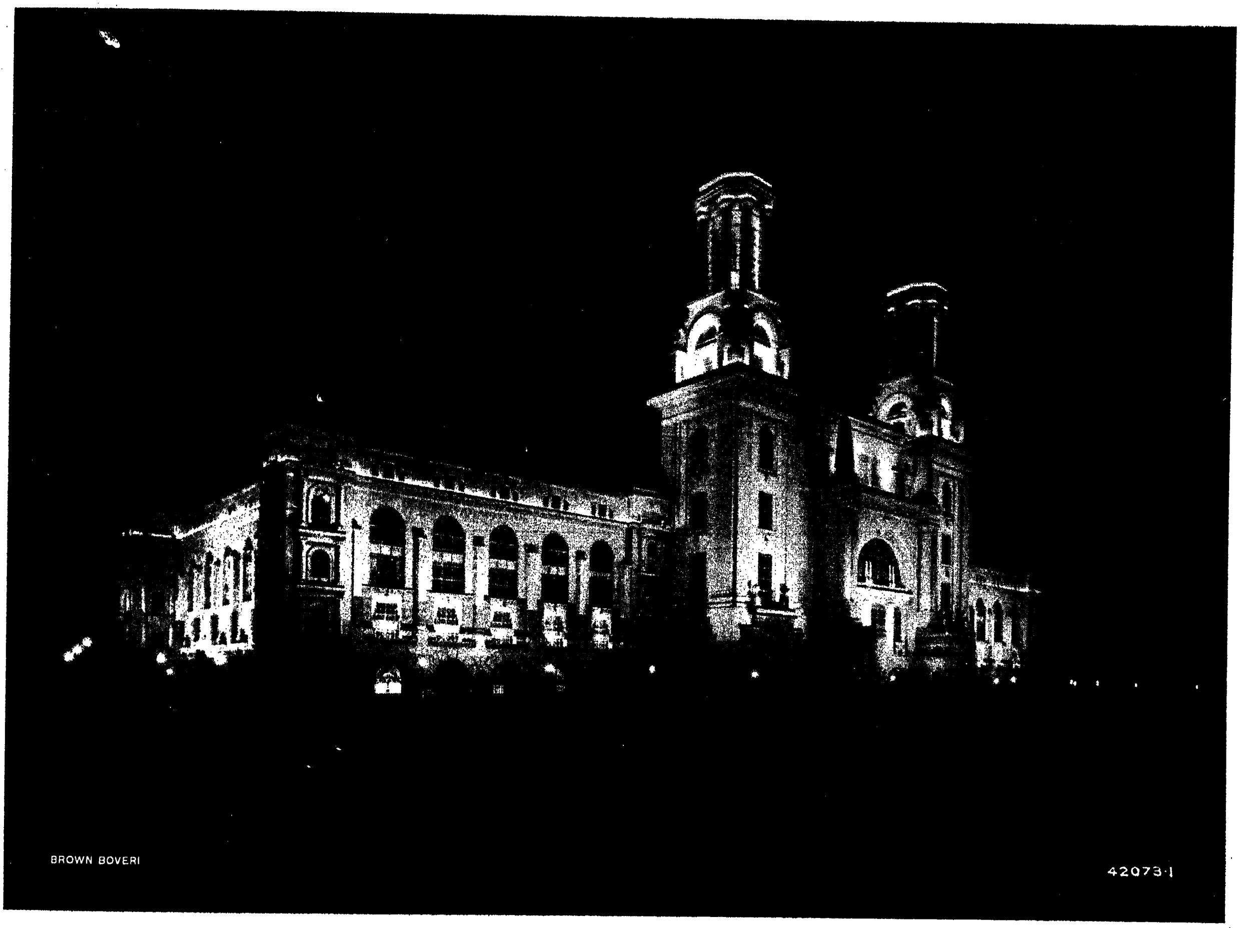


CIA. ITALO-ARGENTINA DE ELECTRICIDAD. NUEVO PUERTO SUPER-POWER STATION, BUENOS AIRES.
(Night photograph.)

CONTENTS:

Printed in Switzerland.

There were three reasons for locating the super-power station in the new "Nuevo Puerto" harbour of Buenos Aires. The first is that the large volume of water required by the condensing plant is available; the second is the feasibility of bringing big freight steamers loaded with solid and liquid fuel right up to the quay side; the third is that the location is at the centre of power consumption. Ground to build the station had to be reclaimed from the bed of the Río La Plata, by erecting a quay wall which encloses off an island of about 145,000 m² from the river. This is shown in the aerial view given in Fig. 1. This photo was taken in January of the year 1930 when work on the buildings and water channels had hardly been begun. The quay wall was already completed but the temporary dam which had been required in order to build it had not yet been demolished. The Río La Plata is shallow and, near Buenos Aires, satisfactory foundation ground is reached just below a layer of river-bed clay. Foundations for all kinds of harbour work are, therefore, easily made.

The plan view (Fig. 3) and elevation (Fig. 4) show the general layout of the super-power station. The first development stage comprised a boiler house

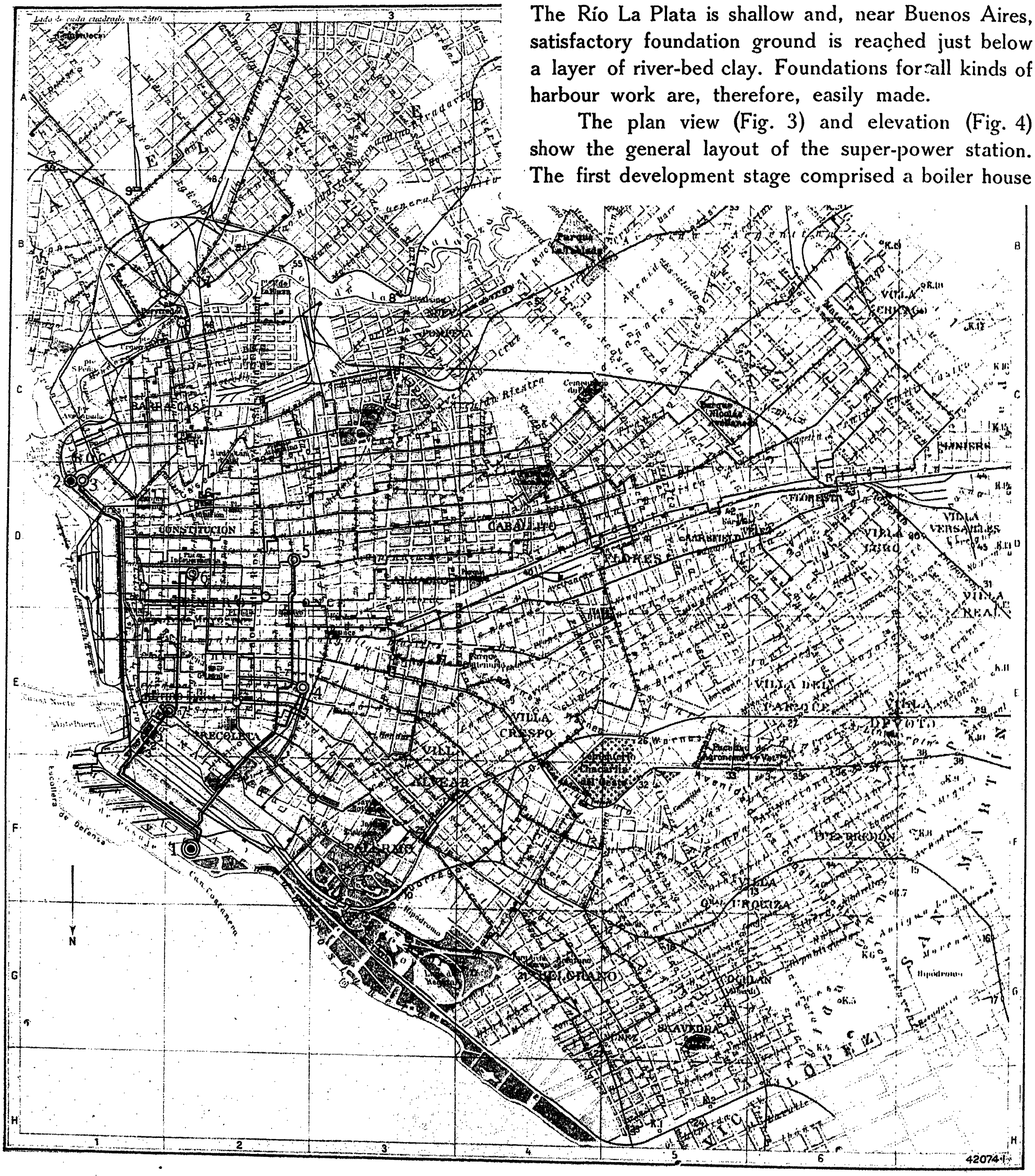
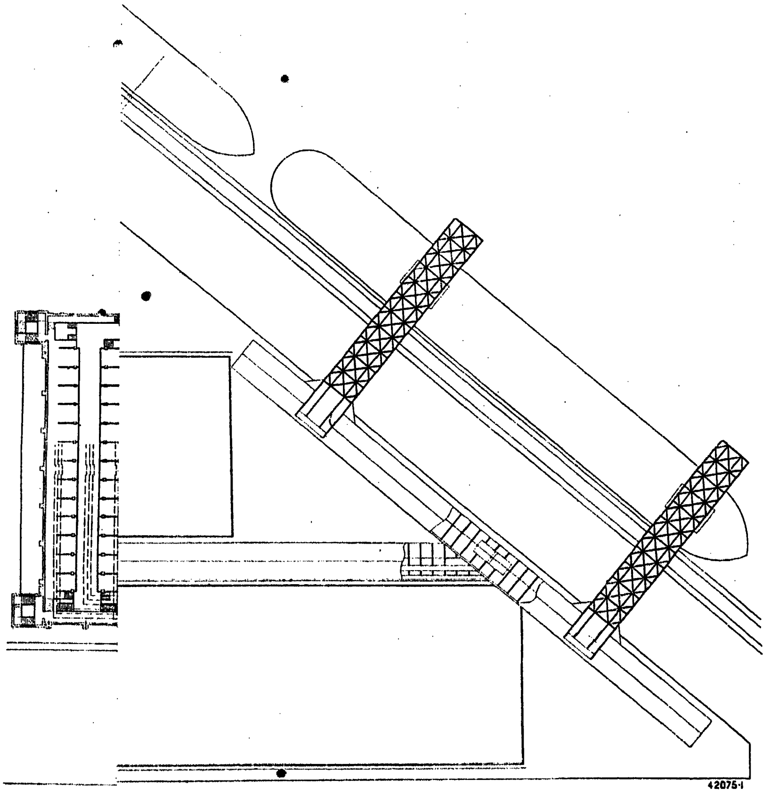
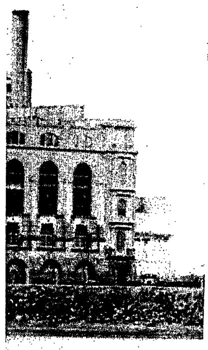


Fig. 2. — Cia. Italo-Argentina de Electricidad, Buenos Aires. General survey plan of power station and substations.

1. Nuevo Puerto super-power station.
2. Pedro Mendoza steam-power plant.
3. Perez Galdos substation.
4. Tucumán substation.
5. Estados Unidos substation.
6. Independencia substation.
7. Santa Fé substation.



›f Nuevo Puerto super-power station.



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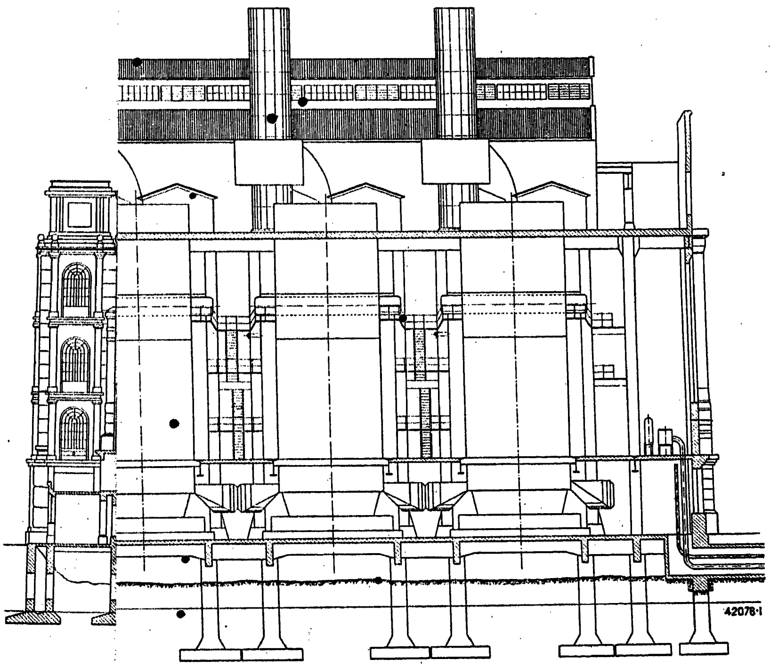

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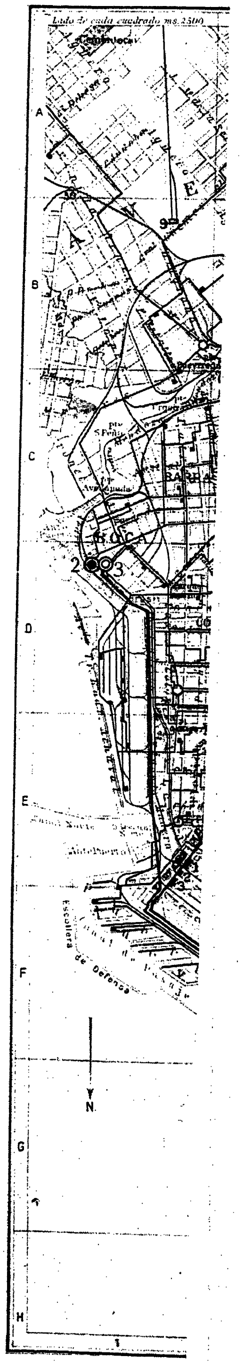

Fig. 2. —
1. Nuevo Puerto super
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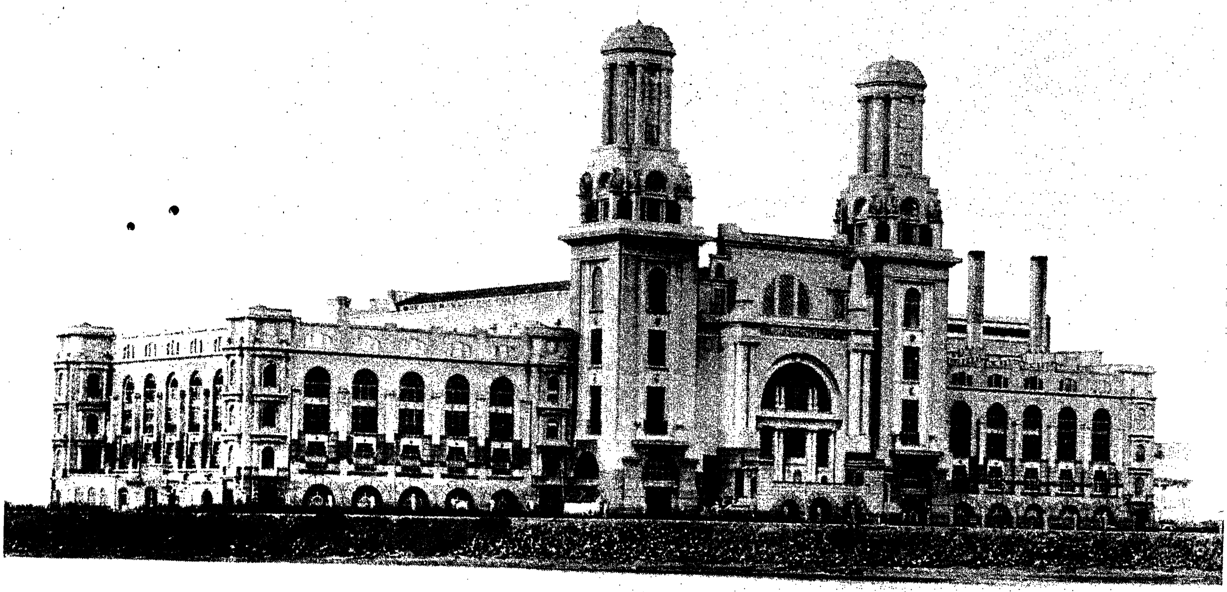

Fig. 5. — Nuevo Puerto super-power station.

with eight boilers. The complete scheme provides for three boiler houses with a total of 24 boilers. The evaporators, feed-water heaters and feed-water tanks are placed in a chamber adjoining the boiler house; this is followed by the main building with the machinery hall containing the three 35,000-kW turbo-sets of the first-development stage; the complete development provides for seven or eight turbo-sets with a total output of 350,000 kW. The station is completed by the building for the transformers and electric auxiliaries, located symmetrically to the boiler house and, finally, by the switchgear plant with outgoing lines, separated by an inner court from the transformer building.

The cooling-water intake is designed, in the first development stage, for a volume of water of 9 m^3/s, and is located on the harbour side opposite the main façade. The water reaches the screen chamber through two channels and from here it is carried by two further channels into the machine house. The floor of the channel is at level — 8 while the floor of the machinery hall is at level + 11 so that there is a difference of level of 19 m between them. This difference has been so chosen that, when the Río La Plata is at its lowest, there will always be enough cooling water for condensation, while the machinery hall cannot be flooded at high-water periods. The level of the Río La Plata has a maximum variation of over 7 m. The discharge channels are located on the left and right of the intake channels, below the machine hall. These convey the water back to the Río La Plata on the side opposite that of the intake (see plan), to avoid the possibility of recirculation.

The water-tube boilers of the Babcock and Wilcox sectional type are provided with economisers and air preheaters and with forced and induced draught system. The furnace chambers are equipped with water-tube cooling which is connected in the circuit of the feed-water supply. The useful heating surface is 1446 m^2. These boilers are built, primarily, for oil fuel. Two of the eight units put in have grates, however, in order to allow of operating them with coal fuel. The other six can also be equipped with grates, if it is found necessary. These boilers are built for a steam pressure of 38 kg/cm^2 at a steam temperature of 440—450° C. The rated output is 50,000 kg/h, the maximum continuous output being 62,500 kg/h and the maximum two-hour output 75,000 kg/h. The fuel oil is brought to the quay side in tankers and stored in big containers shown in the elevation. The coal-conveying plant is not built yet. It has been designed so that the coal will be conveyed by travelling

gantry cranes to the place of storage or else conveyed by belt to the crushers, from whence it will be carried to the bunkers and thence fed to the boiler grates through hoppers.

Fig. 7 shows the machinery hall with the three generating sets of each 35,000 kW built in 1929–1930 by Messrs. Brown, Boveri & Co., Ltd., in Baden. At the time they were completed they were the most powerful turbo-sets existing, working at 3000 r.p.m.

Per unit, arranged transversally, there are two condensers, corresponding to the two exhaust branches, under each turbine. The air cooler for cooling the air used for generator ventilation is placed on the same storey; the condenser pumps are lodged on a third storey.

The turbines are of the three-cylinder type used by Brown Boveri, for over a decade, for outputs of and above 12,000 kW, when the highest efficiencies are called for. Brown Boveri has more than 90 three-cylinder turbines, with an aggregate output of over 2 $^1/_4$ million kW, operating, to-day, all over the world. In the present case, the economic load was fixed at 28,000 kW. The turbines are built for a live-steam pressure of 36 kg/cm^2 abs, 425° C and a cooling-water temperature of 15° C. Acceptance tests proved performance better than guarantees, at all loads. Owing to the high pressure and temperature utilized the high-pressure cylinder of the three-cylinder turbine is built entirely of cast steel. It is relatively small and is carried, at each end, on two feet. These feet on the governor-side end of the cylinder are provided with the Brown Boveri patented hinged suspension which allows quite free expansion of the high-pressure cylinder. The valve chests are mounted independently on both sides of the high-pressure cylinder and each chest carries two automatic nozzle valves with vertical spindles and a main-closing valve with horizontal spindle. The main closing valve can be operated by hand; it is also so designed that it acts as emergency instantaneous-closing device. The whole governing system is without rods, the requisite governing force being transmitted by oil under pressure which results in maximum celerity and precision in governing. The steam flows from the high-pressure cylinder to the intermediate-pressure cylinder through flexible pipes laid under the turbine. As the steam flows in counter sense in the high-pressure and intermediate-pressure cylinders, the two shafts, which are rigidly coupled, are maintained in equilibrium as regards the axial thrust. The steam flows from the intermediate-pressure cylinder to the low-pressure cylinder through two parallel pipes which pass over the turbine. As regards the sense of steam flow, the low-pressure cylinder is symmetrically designed, steam flowing from the centre towards both ends, from whence it reaches the two condensers lodged crosswise below it.

Each cooling-water pump draws water from the channel and corresponding pipe lines carry the water from the condensers back to the discharge channel. Special, isolating gate valves are inserted on these pipe lines which have an 800-mm bore; these valves are controlled by D. C. motors of 1·5 kW output which can close the said valves in three minutes, while closing by hand requires about 15 minutes. Control is by push buttons mounted on a special control board having signal lamps giving the momentary position of the gate valves. Each main set has a control board of this type mounted in the condenser room.

The turbo-generators each of 37,500 kVA output are wound for a terminal voltage of 7000 V and for 50 cycles. They have six terminals so the neutral point can be brought out on the three phases, thus allowing of building in current transformers which are used for differential protection of the generator against internal faults.

The rotors are forged out of one piece, the highest-grade steel alloy, free from internal stresses being used for this purpose. A rotor complete and

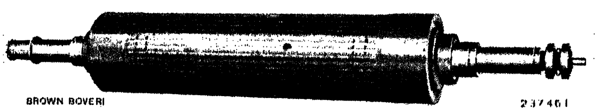

Fig. 6. — Rotor of a 37,500-kVA generator.

ready for mounting weighs 20 t (Fig. 6). This illustration also shows the rotor-end caps of non-magnetic steel which hold the rotor coil heads in position. The use of non-magnetic steel, here, limits losses due to the stray field, considerably.

The stator housing is of steel sheeting and structural iron welded together. This gives light weight combined to a maximum of mechanical rigidity.

The stator winding is built up of stator bars composed of transposed conductors of the well-known Brown Boveri design which reduces losses due to eddy currents in the bars. Each stator bar is covered by a seamless sleeve of micanite put on under carefully regulated conditions of pressure, temperature and duration of operation. This results in a high insulating value with the lowest dielectric losses as well as in long length of life and high mechanical strength. The coil heads are insulated by hand and braced together by insulating pressure plates. This prevents deformation of the coil heads which might otherwise result from the electro-dynamical forces arising during a short circuit.

The supervision of the thermal part of the plant is carried out from a central supervision room, equipped

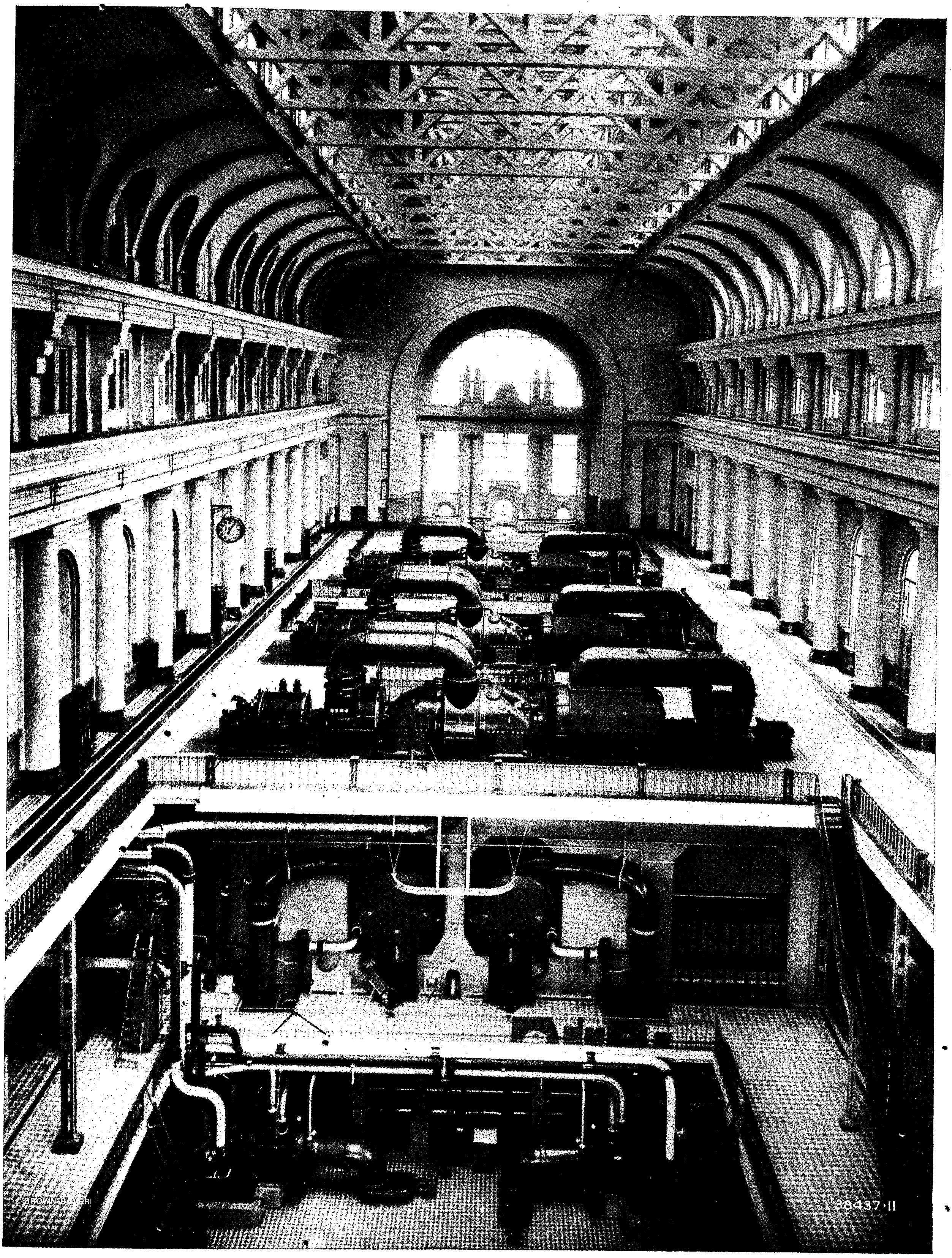

Fig. 7. — Machinery hall of the Nuevo Puerto super-power station.

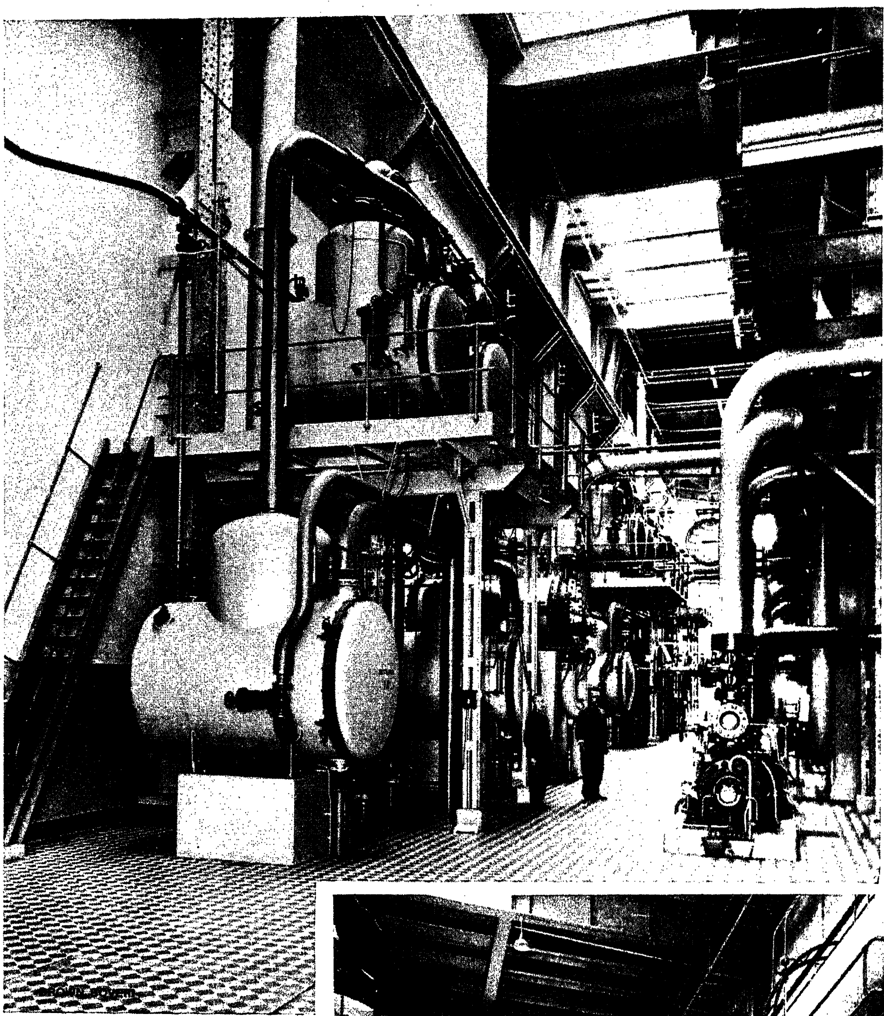

Fig. 10. Evaporators.

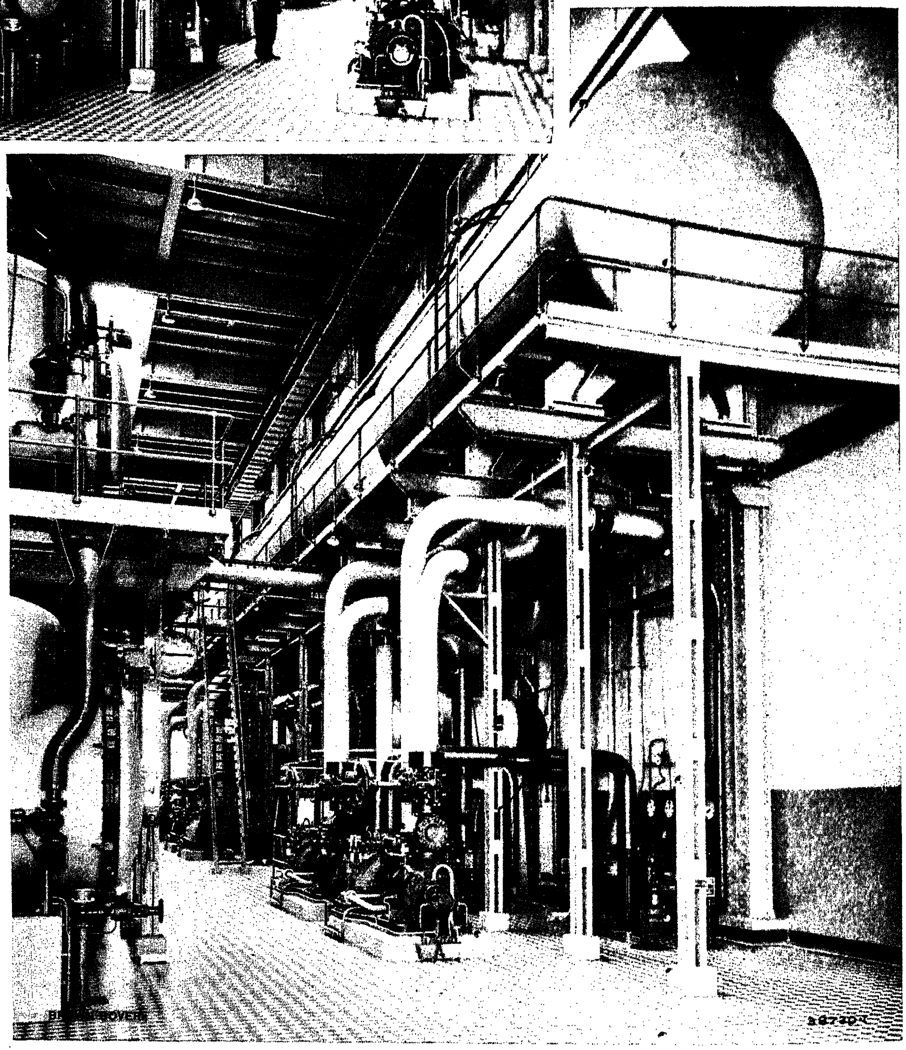

Fig. 11.
Feed-water tanks and pumps.

The evaporators, the feed-water heaters and their pumps are lodged in a special chamber located between the machinery hall and the boiler house and shown in Figs. 10 and 11. Fig. 10 shows clearly the four evaporators which belong to the first turbo-set,

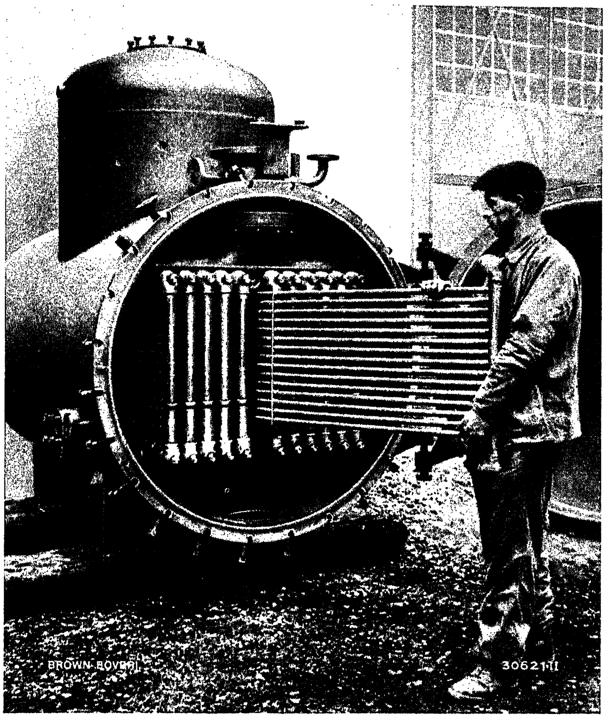

Fig. 12. — Evaporator opened for cleaning.

they are ranged in pairs in two tiers, so that the steam produced in the lower evaporator is used as heating steam in the upper one.

Beside the evaporators is placed the intermediate-pressure feed-water heater which, as mentioned before, is supplied with the heating steam from the second set of evaporators. The intermediate-pressure tanks, placed high and of 50 m^3 capacity, are clearly seen in Fig. 11 along the partition on the boiler-house side. There are two turbo-feed pumps under each intermediate-pressure container and these pumps drive the condensate through the high-pressure feed-water heater into the boilers, according to requirements. Each feed-water pump delivers 165 m^3/h and, therefore, suffices for the economic requirements of one of the main generating sets.

Fig. 12 shows an evaporator opened. As the illustration shows, great value was set on being able to clean the apparatus quickly. Possible deposits of lime appear on the outside of the heating tubes which, as shown, are divided up into separate elements which can be removed for cleaning both easily and quickly.

The governing of the boiler feed pumps is worthy of note. Fig. 13 shows diagrammatically the differential pressure regulation as used on each set of six pumps. Here the Brown Boveri system of oil-pressure governing without rods is also used. The governing system always maintains a feed-water pressure which is some atmospheres above that of the live steam, so that a reliable feed-water supply to the boiler is assured. All auxiliary turbines are supplied with live steam and are built of cast steel. As the pressures are of the order of 36 kg/cm^2, the forces necessary to actuate the governing valves are fairly large and a system of servo-governing is used.

The governing lever g is under the influence of the water pressure which acts from below on the flexible bushing f it is also under the influence of the steam in chamber e and of the additional spring e_1 which reinforces the effect of the steam. The governing piston g_1 adjusts the pressure of the governing oil, which acts on the servo-motor piston c which, in turn fixes the position of the governing piston d and, therefore, of the valve b. The volume passing can be varied by means of handwheel h which influences the tension of auxiliary spring e_1. In order to be able to supervise

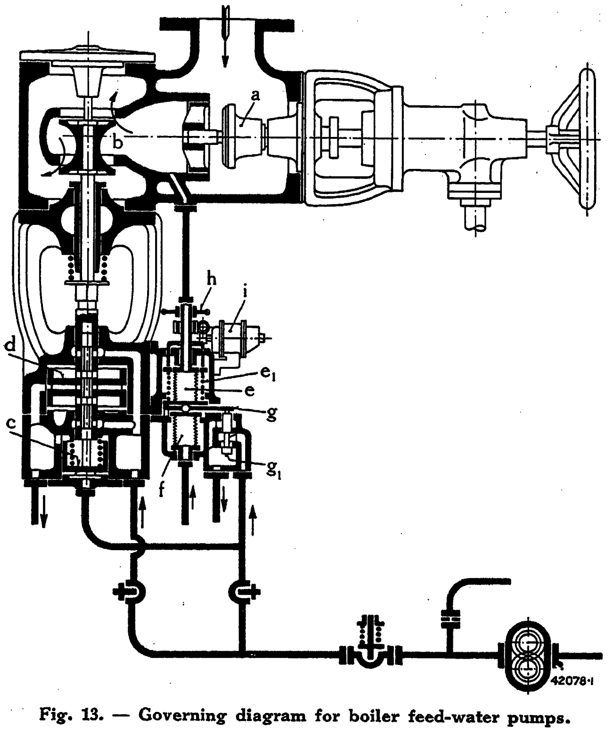

Fig. 13. — Governing diagram for boiler feed-water pumps.

the whole feeding process, a control board is placed in the feed chamber off which can be read, on the one hand, the water level in each feed-water tank and the volumetric supply of each feeding pump. Beside it are placed the push-buttons which allow of setting

at a distance the volumetric discharge of each feed pump, this by the auxiliary spring e_1, being tightened or loosened through the action of the motor i.

The diagram of connections (Fig. 14) shows the general arrangement of the switchgear layout of the super-power station. Each turbo-generator forms a unit with its transformer, which steps up the voltage from 7000 to 27,500 V; there are no connecting bus-bars on the low-voltage side. In this first-development stage, the bus-bars on the high-tension side remain open but, when the whole scheme is completed, they will be closed in a ring and sub-divided into groups by disconnecting switches so that, later, it will be possible to supply different sections of the supply system independently and the short-circuit loads to be withstood will be reduced. The bus-bars of the super-power station also form those of the whole 27,500-V system. Service is so carried out that bus-bar voltage is maintained constant while tappings on the transformers in the various sub-stations allow of adjusting the voltage to the momentary load. In the general diagram of connections, the present development is drawn in full lines and the future development in dotted lines.

The layout of the switchgear proper is shown in the plan given in the plan view Fig. 3. The distri-

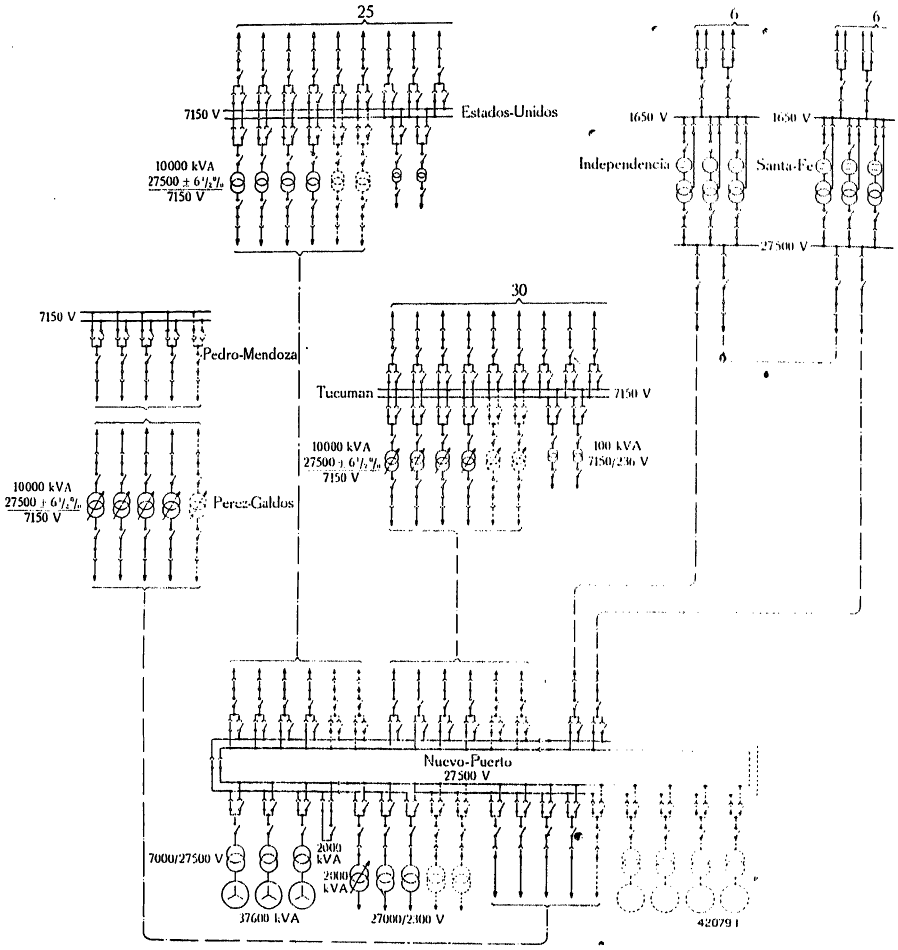

Fig. 14. — General diagram of connections of the new distribution plants.

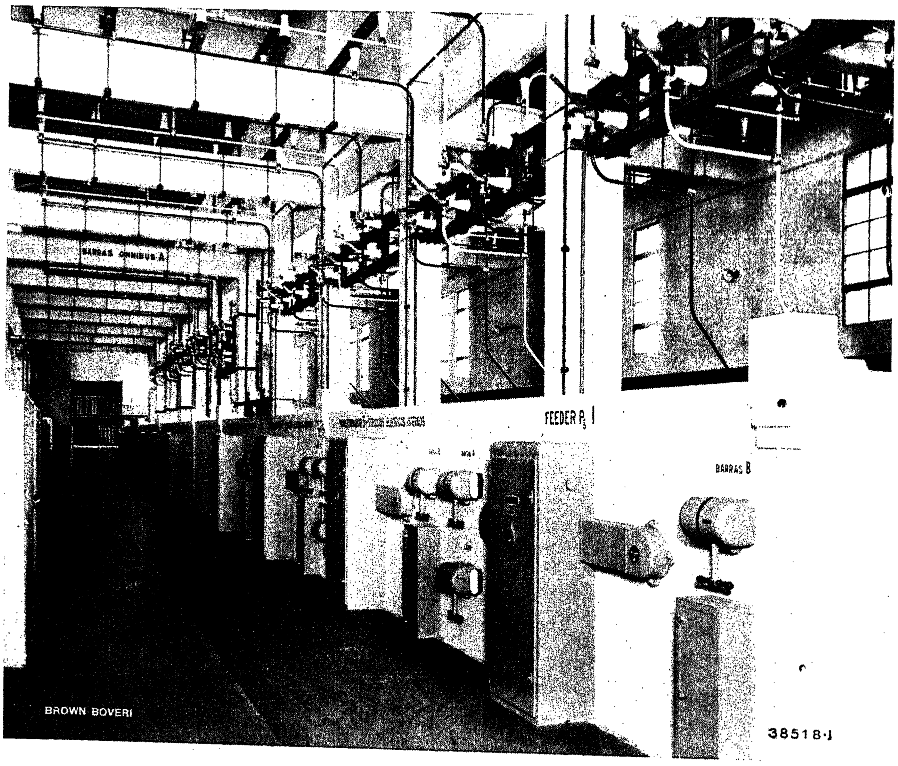

Fig. 15. — 27·5-kV switchgear plant.

bution plant for the auxiliary services is located beside the machinery hall and in the continuation of same. The 2300-V bus-bars are fed from station transformers which are themselves connected to the high-tension bus-bars. For the time being, no separate turbo-set has been put in to supply the auxiliary services, as all the important pumps are driven by auxiliary turbines and are, therefore, independent of the electric system. There are four 2300-V lines for each boiler house and the coal-conveying plant. For the other auxiliary services, the voltage is stepped down to 450 and 225 V; further, there is a storage battery at 220 V.

The main 37,600-kVA transformers connected to the generator sets are lodged in a row in a special building which also contains the three (later five) 2000-kVA station transformers. The 37,600-kVA transformers are built for external oil circulation through coolers while all the other transformers are naturally cooled. The apparatus for the oil-circulation cooling is lodged in special cells and is very accessible. The layout is such that it is easy to clean the coolers and that, if there is a leakage in the cooling system, it is impossible for water to penetrate into the circulation circuit of the oil; to this purpose, measures are taken to maintain a higher pressure in the oil circuit than in the water system. The oil circuit breakers for the generator sets are placed opposite as well as the outgoing leads for auxiliary services and the line to the Perez Galdos substation. The oil circuit breaker design is of the three-tank type and these are countersunk; they are designed for 600,000-kVA rupturing capacity. The disconnecting switches have hand drive and electro-magnetic interlocking to prevent faulty switching. All drives are arranged in the control gangway in groups and in such a manner as to be easy to supervise (Fig. 15).

The outgoing lines to all substations are in another building. As the plan view shows, one bus-bar system was duplicated which did much to simplify the laying of the leads to the outgoing lines located opposite each other.

The main equipment of the control room is a light diagram with a service switchboard panel of the desk type in front of it. As the bus-bars of the power station are, also, the bus-bars of the whole 27,500-V system, it was of importance that the operators should not only be able to supervise conditions in the power station but the whole high-voltage network as well. The light diagram makes this feasible and it proved its great value in practice (Fig. 16). The conditions in the plant proper as well as the signalling back of the position of the switches and breakers of all the substation are reproduced on the light diagram on which all instruments and apparatus are placed in their proper positions on the diagram of connections and this in such a manner that their relative relationships are clearly apparent at a single glance. Thus the plant as a whole is made instantaneously clear to the operator. To increase safety, a fault-proof switching supervisor was incorporated which prevents faults in switching being made. Every switching order transmitted from the control room is first tested automatically as regards its results on the whole plant. If the said operation means a change in the voltage conditions of the plant this is shown up on the light diagram by a flickering light which appears on the machines and lead symbols which are implicated in the operation. The fault-proof switching supervisor which works so that only correct operations can be effected, is so designed that those orders which are transmitted and which are allowable, that is to say without danger, are free to be carried out.

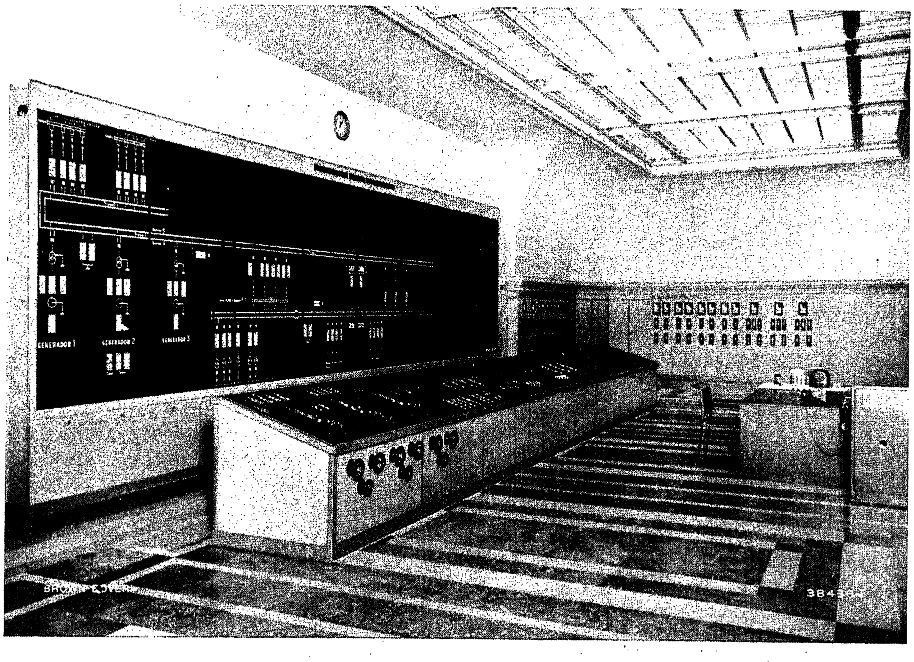

Fig. 16. — Control room with light diagram.

The control apparatus proper is placed on the desk switchboard, being built into a mimic diagram corresponding to the light diagram layout. The desk switchboard is distanced from the light diagram so that the operator gets a proper view of the whole situation before imparting a switching impulse.

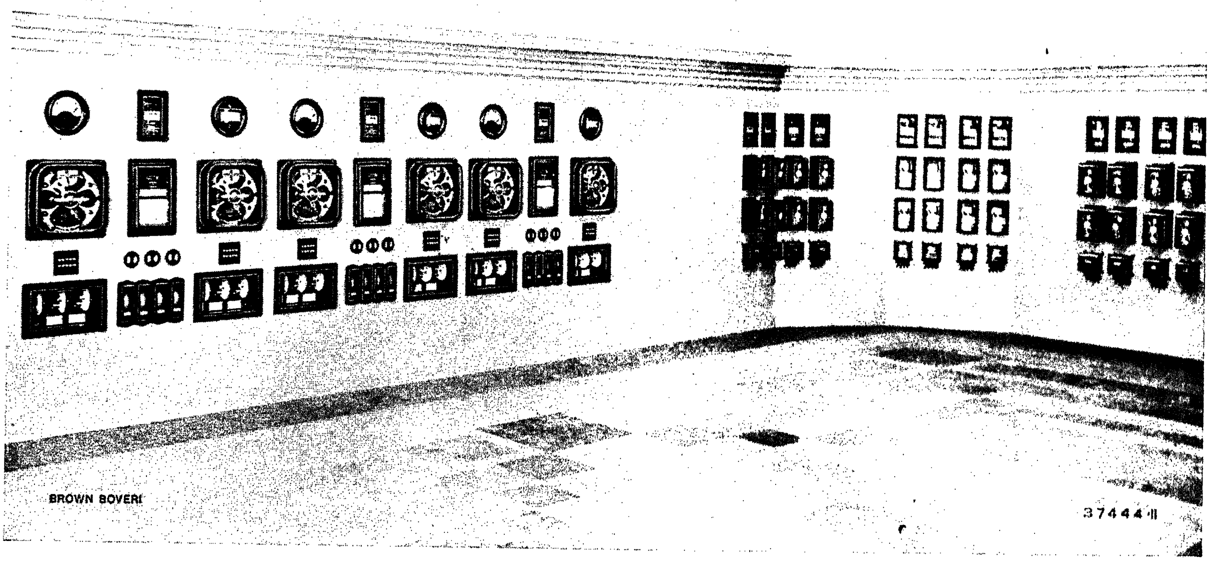

Fig. 17. — Control room with regulators and relay panels.

On both sides and opposite the light diagram are mounted switchboards to carry the regulators and the protective gear (Fig. 17). Each generator-transformer set is equipped with differential relays to afford protection against short circuits between phases or to earth, because the neutral points of the generators and of the high-tension windings of the transformers are earthed over resistances. The distribution networks are protected by Brown Boveri distance relays which assure the desired selectivity with the shortest tripping times even in intermeshed networks. The generators are equipped with automatic voltage regulators so as to hold the voltage constant and to maintain automatically the subdivision of kVA load among the generator units; they also have automatic current regulators to assure the automatic reduction of the excitation of the generators in care of short circuits, which reduces the stresses which arise under short circuits.

There is a separate plant for imparting switching orders and which connects the control room and the machinery hall. This device allows of transmitting the instructions given for operating the sets. By

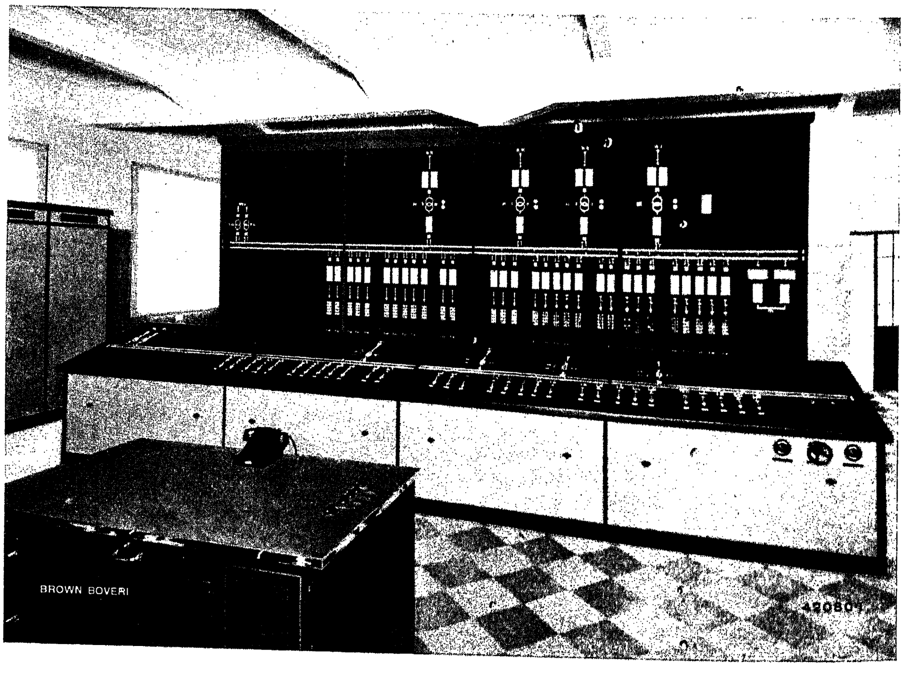

Fig. 18. — Control room with light diagram in the Estados Unidos substation.

actuating signal buttons which are mounted on the control board beside each machine symbol (Fig. 16) a signal lamp is made to light up in the machinery hall as well as a common warning lamp which is provided for each of the three generators, at the same time an acoustic signal is given. The signal button is held down by a mechanical catch, after being depressed, and is only freed again by depression of an acquittal button in the machinery room, after the order has been carried out. Fig. 17 shows the boards with the call and signal lamps on the left wall of the machinery hall; these boards also carry the principal instruments for operating the generator sets.

For the time being, the connection between the super-power station and the Perez Galdos substation is by four Pirelli lead cables of 3×150 mm^2 section. These cables have an oil-paper insulation with an envelope of metalized paper and an iron-clad lead cover. Further, from the super-power house four cables of the same kind go out to the Tucumán substation and four to Estados Unidos substation. The voltage is stepped down in the two latter substations to 7000 V, by means of 10,000-kVA transformers, and the power is then distributed to the town through cables, the rated current carried being 300 A.

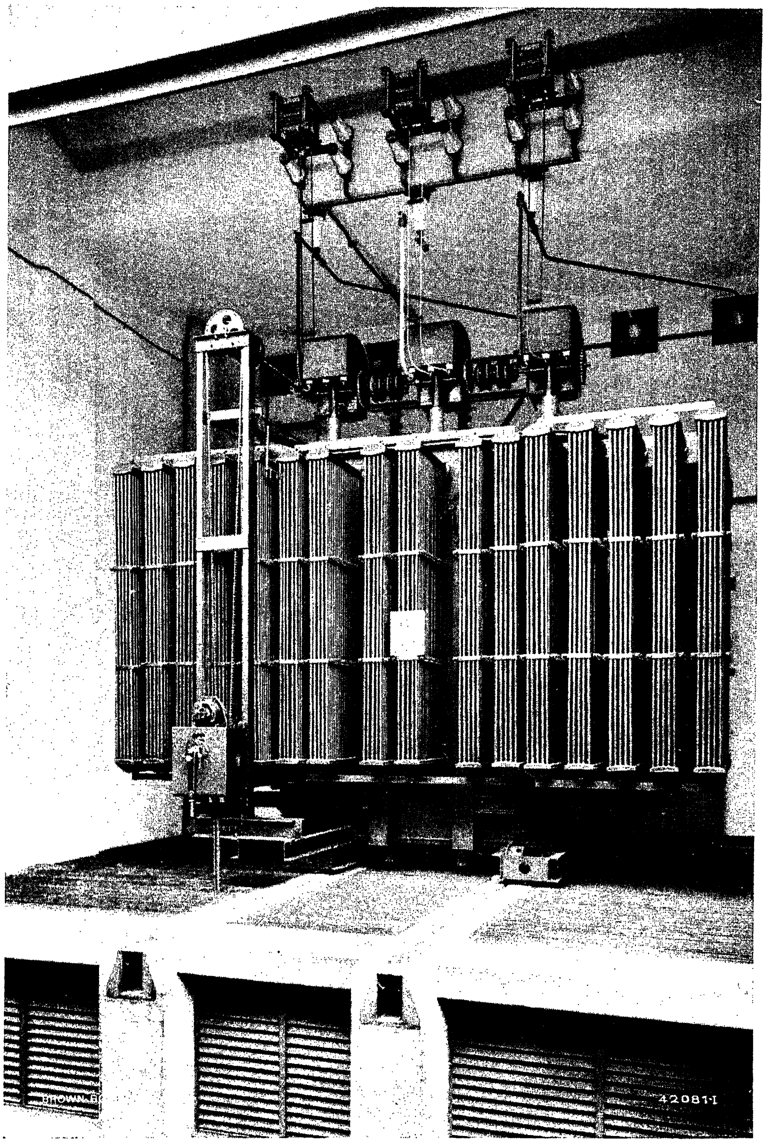

Fig. 19. — 10,000-kVA transformers with built-on step switch, in the Estados Unidos substation.

The two Tucumán and Estados Unidos substations are identical with the exception of the number of outgoing lines, which are 30 and 25 respectively. Each two outgoing lines supply a ring with 20 distribution breakers the positions of which are signalled back, so that the light diagrams of these substations (Fig. 16) show the whole power distribution very clearly.

The four 10,000-kVA transformers of each substation are naturally cooled and have built-on tapping switches designed for remote control (Fig. 19). These tapping switches can be regulated separately or coupled in a group of four, in which case a whole group is controlled by one control switch. In order to prevent too big voltage jumps from one step to another when operating the step switch, the operation is carried out so that the phase steps are changed over separately and consecutively.

The Perez Galdos substation is near the old Pedro Mendoza power house and is controlled from the latter with the help of a light diagram equipped with fault-proof switching supervisor. This substation forms the connection with the existing Pedro Mendoza power house so that power can be exchanged between the two power houses through the said substation.

(MS 890) *J. Broggi. E. von Mülinen. (Mo.)*

NOTICE.

We are in a position to inform our readers that the Stevens Institute of Technology, Hoboken N. J., U. S. A., has conferred the honorary degree of Doctor on our Chief Mechanical Engineer, Mr. Adolph Meyer, in recognition of his outstanding services in the development of thermal machinery. This acknowledgment of his remarkable pioneering work can be taken as a tribute to Swiss industry.

BROWN, BOVERI & COMPANY, LIMITED.

NOTES.

Brown Boveri Velox steam-generating plant in the Haifa Power Station of the Palestine Electric Corp., Ltd.

Decimal index 621. 181. 39 (569. 2).

THE object of the Palestine Electric Corp., Ltd., the headquarters of which are in Haifa, is the supply of electric power to Palestine. Up till a few years ago, the only generating plants which this company had available for power supply were a few small Diesel-electric stations in Haifa and other localities. In the year 1932, however, a first big hydraulic plant on the Jordan near the mouth of the Jarmuchs, which contained three generating units of 6000 kW, was put into regular service. There are other hydro-electric power stations being planned, at present, which will be situated on the river above this first plant. These power stations will make use of the lake of Tiberias (Genezareth) as a storage basin which will store up a portion of the water which falls in the rainy season between January and March and will make it available for summer months. Owing to the numerous irrigation plants which must be kept supplied with power in summer, the electric power requirements at that season are greater in Palestine than at other seasons, which is contrary to what is generally met with in other countries. In order to meet the rapidly increasing requirements of the country and also to second the hydro-electric plants, during the dry season, it was decided to build a big steam plant in Haifa, which had to be close to the sea in order to insure getting enough cooling water. Work on this power station was started in the year 1934. The first development stage comprises two turbo-sets, namely:— one unit of 6000 kW and one of 12,000 kW while the putting in of a third set, 12,000 kW, is contemplated.

Only oil fuel could be considered. One of the Irak Petroleum Company Ltd. pipe lines ends at Haifa; this line being used to convey crude oil, by pumping, from the wells in Mesopotamia to the coast, from whence it is shipped away in tankers. At present, this oil is not used for boiler fuel as it still contains all its by-products and it is more economical to use the residue of the crude oil as fuel namely mazout, a heavy fluid obtainable from oversea refining plants. When oil is refined in Palestine, itself, as is planned for the future, it will be become still cheaper to use mazout.

For the time being, the power station contains two Velox steam generators each to produce 34·5 tons of steam per hour at a pressure of 27 kg/cm^2 abs and at a steam temperature of 450° C at the boiler outlet. Thus, a Velox unit suffices to supply the 6000-kW set with all accessories, while two Velox units are required for the 12,000-kW set under full load.

The first of the two Velox plants mentioned (see illustration on inside of cover to this number) was started up in the spring of 1935 and has, already, operated for 2000 hours. The second Velox was ordered at the end of 1934 and was completely erected by the end of July 1935. Both Velox steam generators were delivered from works in the exceptionally short time of 4 months, which includes very thorough full-load tests on our test bed.

On August 20th, we received the order for the third Velox steam generator, to be of the same output and design as the preceding ones delivered to the Haifa plant.

It is a remarkable fact that the ground area taken up by all three Velox steam generators, each of 34 t/h, together is not greater than that required for two ordinary type boilers each of half the output of one of the Velox units. The shipping weight of one Velox with accessories is only a fraction (about 1/10) of that of an ordinary boiler with brick work. This shows how much lower the freight charges for Velox units are than those for ordinary boilers, which fact is of great importance in oversea plants. Similarly, the erection of a Velox, which can be completely mounted and tested in the shops before despatch, takes up less time and costs less than with other types of boiler, the first complete erection of which can only take place on site.

(MS 942) *W. Roth. (Mo.)*

Reliability of Brown Boveri material.

Decimal index 6 (009. 2) : 621. 165.

THE Brown Boveri Review of January/February 1933, page 2, reported that a 3000-kW Brown Boveri turbo-set, running in the Berlin-Steglitz Electrical Works, had been operating continuously for 20 years without giving rise to any trouble whatever, and no parts having had to be replaced.

A similar case is reported on, here, namely that of a Brown Boveri turbo-set of 4000 kW output which has been installed in the Warsaw Municipal Electricity Works since the year 1914. This set is composed of a standard one-cylinder turbine direct-coupled to a three-phase generator delivering 5000 kVA, 5250 V, 50 cycles, there being, as well, a double surface condenser and condensing-pump set with motor drive. This set has been running for more than 20 years, to the complete satisfaction of the owners and is a speaking proof of the reliability of Brown Boveri turbine design.

In the month of June of this year, the set was thoroughly overhauled and the steam consumption measured immediately afterwards. The results of these measurements are especially remarkable:— *the originally guaranteed steam consumption of the turbine is still maintained to-day.* This result is due, to a great extent, to the excellent state of preservation of the blading with special reference to the reaction part of the blading which is made of special brass. Credit must also be given to the careful attendance bestowed on the unit in the works of the Warsaw Municipality; the machine being carefully dried out every time it is stopped.

Even at the period when the machine was built, Brown Boveri had perfected their system of turbine governing, a system working with oil pressure controlled by the governor and having no transmission rods. The reliable and precise operation of the said governing gear and the great simplicity of the turbine design contributed to the very satisfactory operation of this machine.

A whole list of similar cases of Brown Boveri turbines, having been in service for years, could be drawn up, some units even showing continuous service during 30 years and more.

(MS 931) *G. Leidig. (Mo.)*

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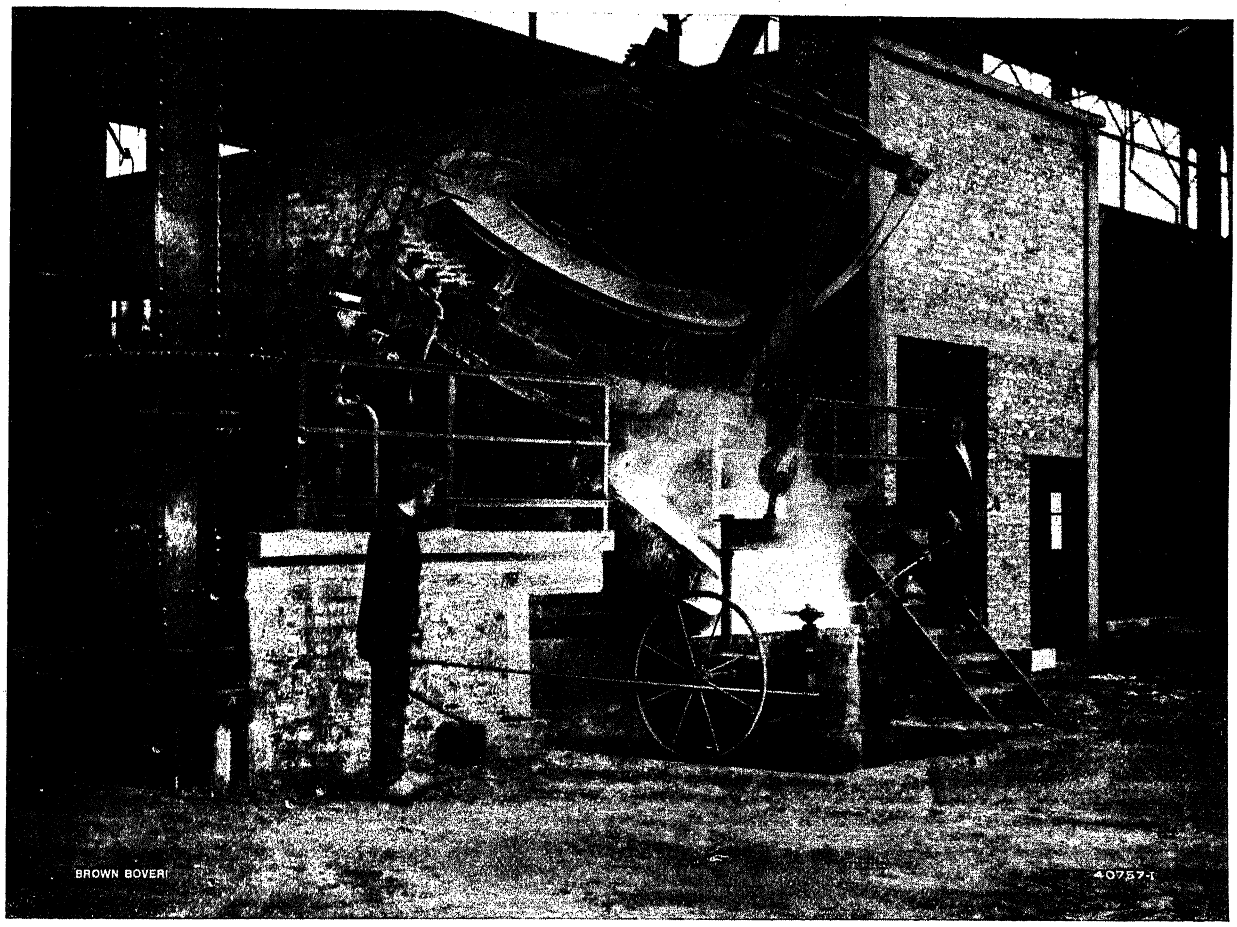


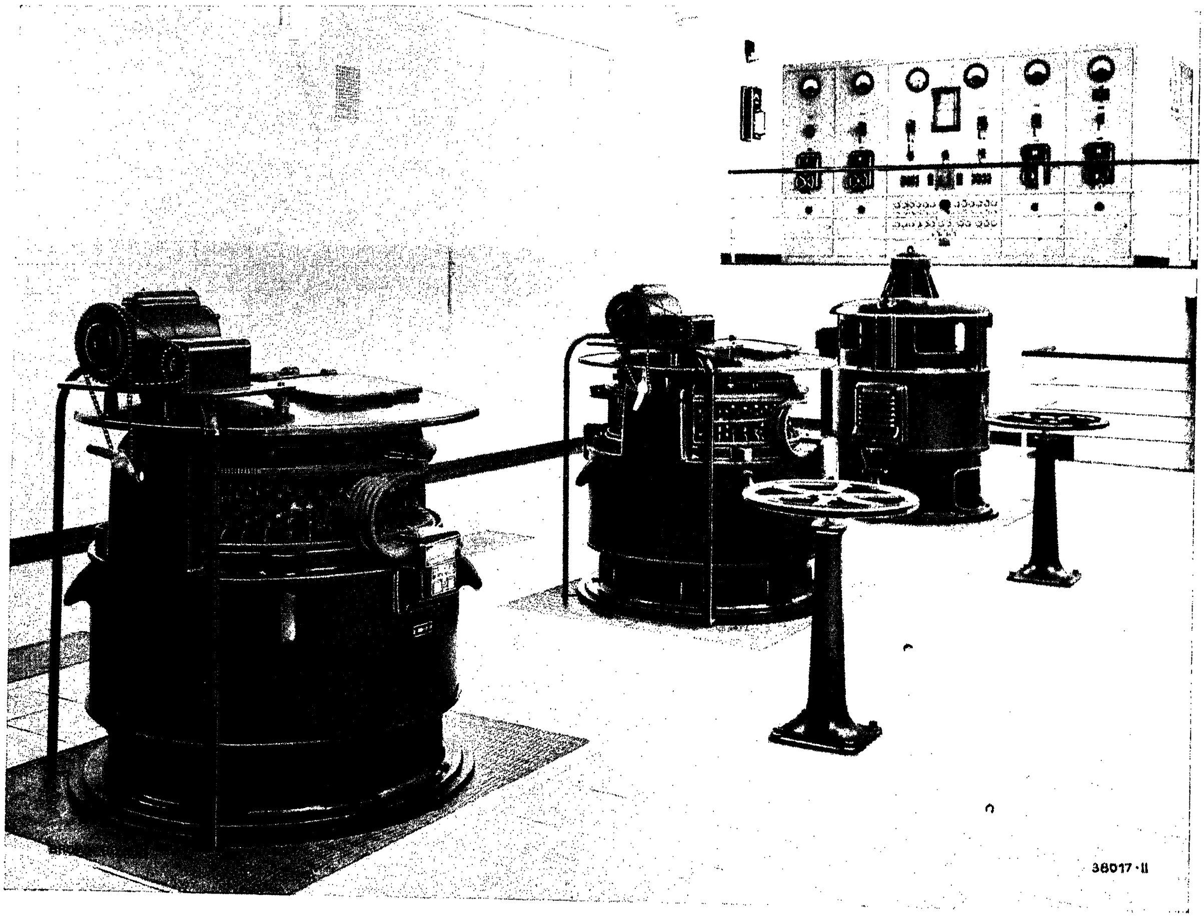
ALLARD STEEL WORKS AT MONT SUR MARCHIENNE (BELGIUM).

Brown Boveri arc-melting furnace for steel. Capacity 3—4 t, with Brown Boveri automatic electrode-control gear.

CONTENTS:

COMPLETE EQUIPMENTS FOR PUMPING STATIONS

FOR EVERY KIND OF CURRENT AND EVERY VOLTAGE



THE GIESSLIWEG DRAINAGE PUMPING STATION, BASLE.

Foreground:— Two three-phase shunt commutator motors each 80 kW, 580—430 r. p. m., with automatic speed regulation.
Background:— One three-phase slip-ring motor 120 kW, 485 r. p. m., with automatic contactor control.
All motors drive vertical-shaft pumps and operate at 500 V, 50 cycles.

EQUIPMENT OF AUTOMATIC PUMPING STATIONS·

WITH THREE-PHASE A.-C. AND D.-C. MOTORS FOR REGULATION BY FLOAT DEVICE OR WATER-LEVEL REMOTE RECORDER; BY PRESSURE SWITCH OR BY CONTACT-TYPE MANOMETER, AS WELL AS BY TIME SWITCH - THREE-PHASE SHUNT COMMUTATOR MOTORS FOR AUTOMATIC SPEED REGULATION - PROTECTIVE CONNECTIONS.

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXII NOVEMBER, 1935 No. 11

THE BROWN BOVERI AIR-BLAST HIGH-SPEED CIRCUIT BREAKER.

Decimal index 621.316.57.064.241.

I. GENERAL NOTES.

THE application of compressed air to the extinguishing of the electric arc was first suggested at the beginning of the century. The different solutions proposed and patented were not, however, followed by the appearance on the market of practical breaker designs and it was not until the year 1922, that an air-blast circuit breaker was built by Brown Boveri and tried out with successful results in their testing plant. The power available at that time, for testing purposes, was 15,000 kVA, in the form of single-phase current at 8 kV. The results attained were very promising, indeed, but further development of the breaker could not be proceeded with, immediately, owing to the lack of a high-power testing plant, which is essential to the pursuit of the exhaustive tests required to develop a new type of apparatus of this nature.

Therefore, it was only much more recently that the basic principles of the new breakers could be clearly determined, namely, when the Brown Boveri high-power testing plant was put up. It was then possible to make analytical tests and to define clearly what forms the essential parts of the breaker organs should be given, in order to produce the best possible arc-extinguishing conditions. Many thousands of short-circuit tests were carried out and furnished data which determine the factors governing arc rupturing, quantitatively and qualitatively; the work carried out proving, once again, how absolutely essential a high-power testing plant is to the development of reliable breaker designs.

Based on this systematic research work, Brown Boveri has now brought out a graded series of three-pole in-door circuit breakers for all voltages up to 50 kV, ranging from 400 to 1000 A and for rupturing capacities of 100 to 600 MVA.

II. DESIGN.

The general design of the circuit breaker is shown in Figs. 1 and 2. The compressed-air tank 1 forms the base of the breaker, on which the active parts are mounted. This tank has pipe connections for joining it to the compressed-air supply system. The compressed-air tank is horizontally placed and the air-blast valve 2 is fitted on the top of it. Hollow insulator supports secured to the tank carry the active elements of the breaker. The arcing chambers 3 are secured to the three upper insulator supports. These arcing chambers carry the exhaust coolers 4. There are disconnecting contacts 5 connected in series with the arcing chambers, and mechanically interconnected, their fulcrams being on the three lower insulator supports. The operating levers 6, which are partly made of insulating material, control the disconnecting contacts and are actuated by breaker shaft 7. Two compressed-air pistons 8 and 9, governed either electrically or by hand by the control valves 10 and 11, actuate the breaker shaft 7.

III. MODE OF OPERATION.

1. *The opening of the breaker.*—Opening of the breaker is effected by means of air-blast valve 2, itself controlled by the solenoid-operated valve 11. When valve 2 is opened, compressed-air in considerable quantities rushes through the said valve into the distribution duct 12 and, thus, to the three hollow upper insulator supports; through these it reaches the arcing chambers 3. Each of the latter contains a fixed contact 13 and a movable contact 14. The movable contact termed extinguishing contact is designed as a piston and kept pressed by spring action against the fixed contact. As soon as the air pressure in the arcing chamber rises, this movable contact is driven away by the

compressed air, the movement being really a very small displacement. The mass of the moving contact thus displaced is very insignificant as compared to the forces acting on it so that the rupture is extraordinarily rapid and absolutely certain, when the air pressure is applied. Through the opening of the contacts an electric arc is formed which is driven through the fixed nozzle-shaped contact by the rush of compressed air. The air blast envelops the arc on all sides and streams along its length, sapping its energy and causing it to extinguish in a very short space of time indeed. While this process is going on, the switching-out cylinder 9 connected to distribution pipe 12 is put under air pressure. The piston of cylinder 9, acting through breaker shaft 7 and rods 6, causes the disconnecting contacts 5 to open. The time required for the opening of the disconnecting contacts is relatively long as compared to that required for opening the arcing contacts and extinguishing the arc, so that the disconnecting contacts open under no current a certain time after the extinction of the arc, therefore under no load. An auxiliary contact 15 mounted on the shaft of the breaker interrupts the current actuating the solenoid-operated valve 11, as soon as the disconnecting contacts are open. This valve then closes the air supply to the air-blast valve 2 and, at the same time, lets the air remaining on the reverse side of the blast valve stream out. The blast valve then closes under the influence of the pressure of the air remaining in the compressed-air tank and this causes the pressure in the arcing chambers to fall which is followed by the arcing contacts coming together again under the force of the spring. The air blast required to rupture the arc causes the pressure in the air-tank to fall to about half its original value. The tank being always connected to a compressed-air supply, air again flows to the said tank and the breaker is ready to act again. The question of readiness for service is touched on again in the next paragraph.

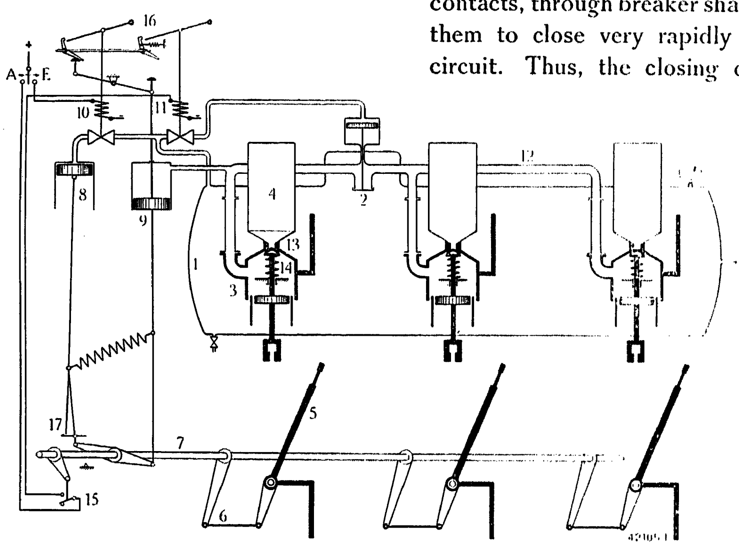


Fig. 1. — Diagrammatic drawing of the Brown Boveri air-blast high-speed circuit breaker.

2. *The closing of the breaker.*—In order to close the breaker, control valve 10 is actuated thus admitting compressed air to closing cylinder 8. The piston of this cylinder moves the disconnecting contacts, through breaker shaft 7 and rods 6, causing them to close very rapidly which closes the main circuit. Thus, the closing of the breaker, always takes place in air under atmospheric pressure. Thorough tests have proved that the breaker can be closed in this way on a short circuit without the least harm, on condition that the design of the contacts be suitable and that the closing or contact-making speeds be the right ones. Under the correct conditions, there is, practically, no sparking or burning of contacts.
3. *Interlocks.*—By means of a simple interlock 16, all switching operations once initiated are forcibly

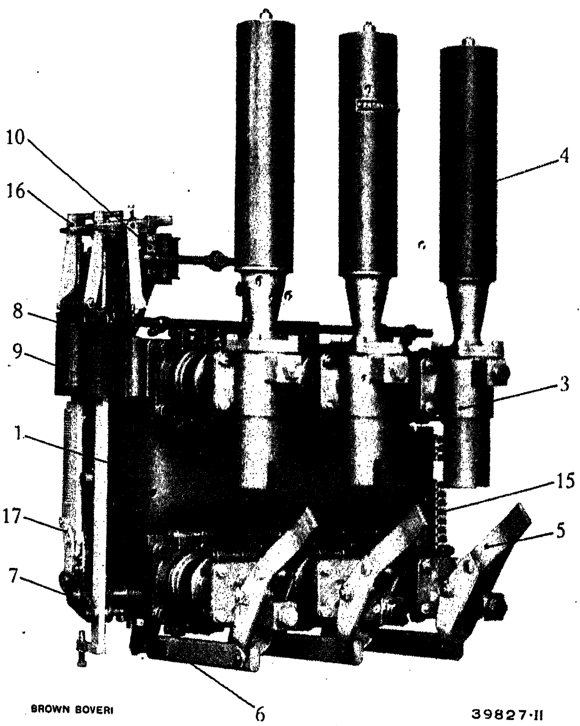


Fig. 2. — Brown Boveri air-blast high-speed circuit breaker.
Rated voltage . . . . 6.4 kV.
Rated current . . . . 400 A.
Rupturing capacity . . 100 MVA.

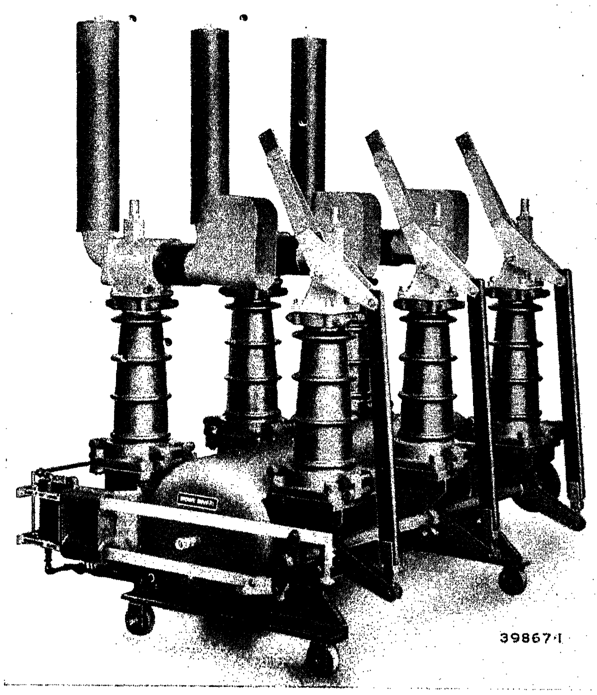


Fig. 3. Brown Boveri air-blast high-speed circuit breaker.
Rated voltage . . . . 50 kV.
Rated current . . . . 640 A.
Rupturing capacity . . 600 MVA.

carried out to completion, under all conditions. A special joint 17 prevents the breaker hunting.

The oscillograms of Fig. 4 allow of following very clearly the performance of the breaker, as just described. These oscillograms show the closing and opening of a 50-kV air-blast high-speed circuit breaker, 50 cycles. The test was carried out at full voltage both when closing on 745,000 kVA and when rupturing 550,000 kVA. The time between closing and opening, that is the duration of the short circuit, was chosen intentionally long enough to separate distinctly the oscillograms of both operations. Under ordinary service conditions, the duration of a short circuit is considerably shorter and dependent, in the first place, on the setting of the protective relay. In the oscillograms:—

a and b show current and voltage curves in phase U;
c and d show current and voltage curves in phase V;
f and g show current and voltage curves in phase W;
e curve showing the opening and closing time of the blast valve;
h curve showing the opening and closing time of the disconnecting contacts;
i curve showing the variations of air pressure in the arcing chambers.

The step-like formation of curves e and h is due to the method of recording and is in no way caused by breaker action. The variation of the pressure curve i has been recorded by means of A. C. at a frequency of 1000 cycles.

The sequence of switching operations is clearly shown in the oscillogram, in which the following moments are recorded:— 1. Closing the disconnecting contacts. 2. Beginning of the short circuit. 3. Opening of the blast valve. 4. Pressure rise in the arcing chambers. 5. Beginning of the rupture. 6. End of the rupture. 7. Opening of the disconnecting contacts. 8. Closing of the blast valve.

The curve of the short-circuit current shows clearly the perfectly satisfactory closing of the breaker on a short circuit. The voltage curve shows that the arc is extinguished in less than 1/100 of a second. The two verticals in the oscillogram denote the beginning of the opening of the blast valve and the end of the arc rupture. The time entailed is about 1·5/100 of a second. This proves the extraordinarily high speed of performance, viz. opening of air-blast valve, rise in pressure, movement of the arcing contact and extinction of the arc. The maximum air pressure is hardly reached in the arcing chamber before the arc has gone out.

No other design of breaker *has ever attained* such short operating times and technical literature contains no claims that any breaker ever built can equal this performance. The Brown Boveri breaker has, indeed, every claim to be termed a *high-speed*

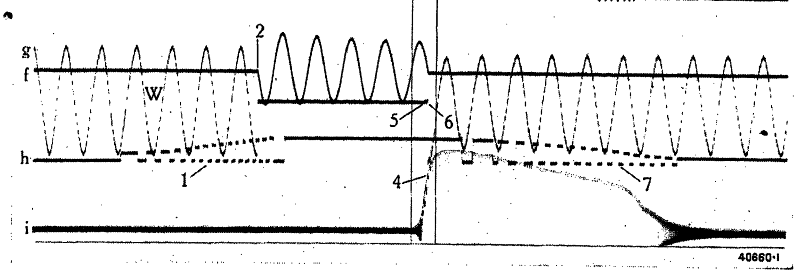


Fig. 4. — Oscillogram of a three-pole closing and opening operation performed by a 50-kV air-blast high-speed circuit breaker, 50 cycles.

Voltage before short circuit	56 kV.	Three-pole closing on	745 MVA.
Rupturing current	6600 A.	Three-pole rupture of	550 MVA.
Recovery voltage	48·1 kV.	Duration of arc	about 1/2 half-cycle.

breaker and it complies with the most stringent requirements as to speed of operation which are imposed in connection with the selective protection of distribution networks. The oscillograms show clearly that the disconnecting contacts always open under no load, as their movement is initiated only about 2/100 of a second after the current has been cut off and the separation proper of the disconnecting contacts only takes place after about 5/100 of a second. Shortly before reaching their open position, they impart the closing impulse to the air-blast valve (through the agency of an auxiliary contact on the breaker shaft). There is, thus, a minimum of compressed air wasted.

IV. WORKING PRESSURE AND READINESS FOR SERVICE.

The average ordinary working pressure of the breaker is 8 to 13 kg/cm^2 gauge, according to the rupturing capacity. In plants where there are breakers using two different air pressures, the air is compressed to the higher pressure and passed through a reduction valve before being used for the lower pressure. If the air pressure in the distribution plant drops owing to some trouble, an alarm sounds. The breakers on the same air-distributing system are not affected as their pipe connections to the air-distributing plant have check valves. It is, thus, impossible that air should flow back from the air tanks to the distribution system.

It was mentioned in the preceding paragraphs that the air used up for an opening operation is immediately replaced, as the breaker is in constant communication with the compressed-air distributing plant. Thus, the air tank has always sufficient air for an opening and for a closing operation. As to the problem of where the stand-by storage of air should be located there are two different solutions:— Either the compressed-air tank is chosen so big that its contents suffice for two or three closing and opening operations or else the tank is dimensioned for one opening and one closing only, in which case sufficient air storage in the form of stand-by air tanks inserted on the compressed-air distribution system must be provided. Brown Boveri has chosen the second solution as it has several advantages over the other, namely:— A big air tank on the breaker itself is often difficult or impossible to lodge in the available space and big tanks make it difficult to gain access to other apparatus in their vicinity; the amount of air which has to be stored in the tank of each breaker, when there are no stand-by tanks is generally far too great. For example, a plant with 20 breakers each with its own tank would require a storage sufficient for 60 closings and openings that is to say an amount of air which hardly ever gets entirely used up. If, on the contrary, the storage is placed in the air distribution plant the breakers are much less voluminous and can be designed in whatever form is best for building into the plant under consideration, while taking up little room. The

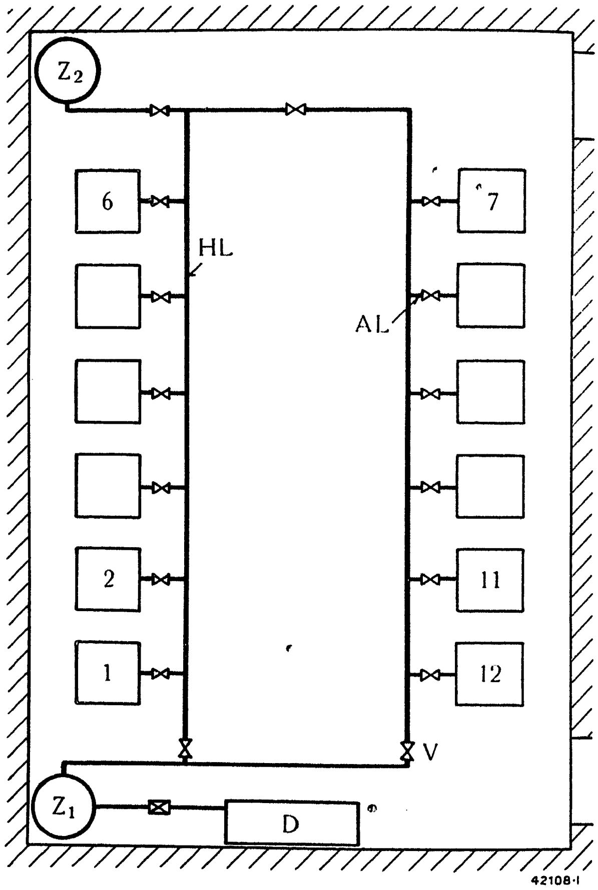


Fig. 5. — General diagrammatic layout of the compressed-air generating and distributing plant in a station containing 12 breakers.

1—12. Air-blast high-speed circuit breakers.
D. Compressed-air generator.
Z_1, Z_2. Additional air containers.
V. Valve.
HL Main distribution pipe.
AL. Branch pipe.

stand-by air tanks can, practically, be located anywhere in the switchgear plant and, thus, whatever available space there is can be taken advantage of; further the capacity of these stand-by tanks can be chosen as big as the requirements of the plant make necessary. Fig. 5 shows the diagrammatic layout and general arrangement of the compressed-air generating and distributing plant in a station containing twelve breakers. The stand-by tanks are lodged in two corners which would, otherwise, have remained unused. These tanks are dimensioned to meet the requirements of the breaker service and allow of about twenty opening and closing operations being carried out without the intervention of the compressed-air generating plant. In order to determine what time was required to fill up the tank of the breaker proper after an opening operation, the stand-by tank Z_2 was cut out and

valve V was closed. Thus, very disfavourable conditions for breaker supply were artificially created. It was shown, however, what time was required to fill up breaker 1 which is closest to stand-by tank Z_1 and breaker 12 which is furthest away. For breaker 1 the time required was 2·0 seconds and for breaker 12, 2·6 seconds, this with a main air distribution pipe of 19 mm bore and branch pipes of 10 mm bore. This shows that the times are well within the limits which can be reasonably demanded in order to insure readiness for service.

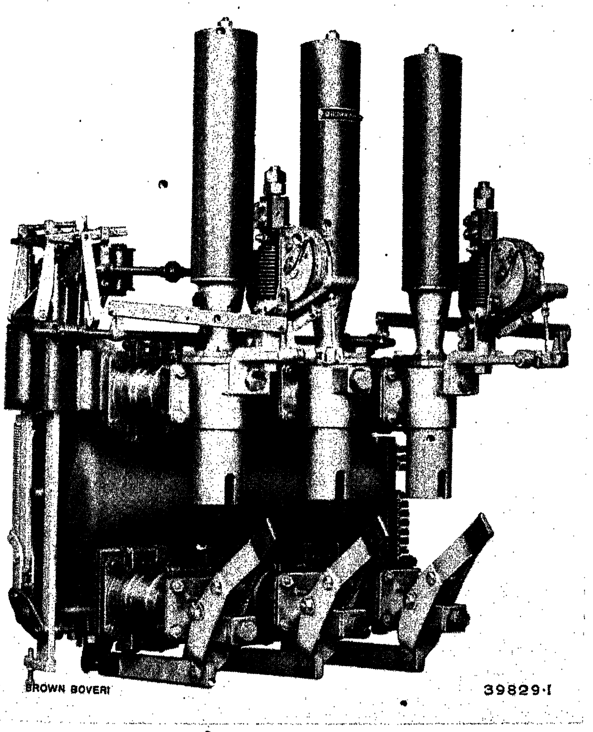
It should be specially mentioned that trouble very rarely occurs on compressed-air breakers because their design has reached such a high degree of perfection, to-day. Further, there is, practically, never any trouble on the compressed-air distribution system, on condition that the pipe lines be properly laid, that is to say so placed that they cannot be attained by electric arcs which may occur in a switchgear plant as the result of atmospheric disturbances, for example. The reliability of a compressed-air generating and distribution plant is as great and even greater than that of any other generating plant used to produce power for operating circuit breakers.

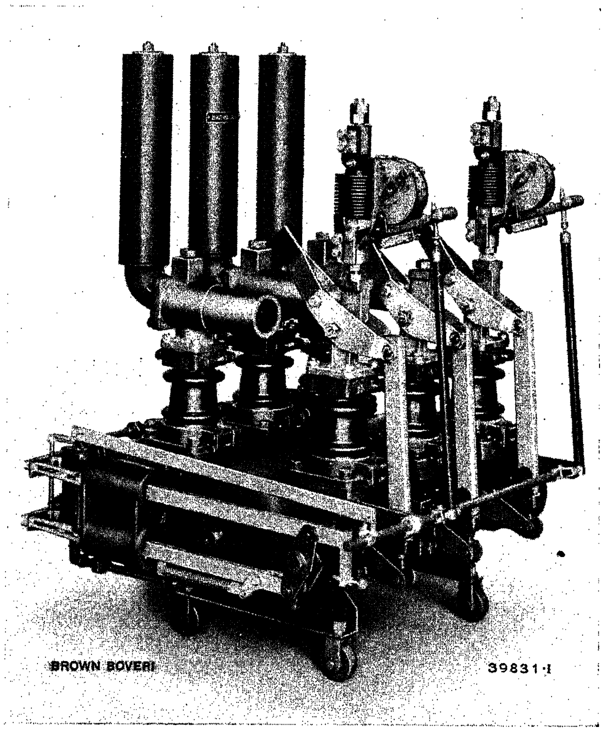
V. NOISE.

The exhaust coolers mounted on the arcing chambers are designed to cool off the hot gases which are generated and to render them inocuous to the high-voltage plant. They also muffle the noise of the breaker operating. It was found possible to moderate satisfactorily the noise caused by rupturing the arc, this at no load and under load. There is no detonation but only a hissing sound similar to that produced by any air tank being discharged under a similar pressure. All ruptures of short circuits under the guaranteed rupturing loads produce similar noises, whether the breakers used are of the oil, water or air-blast types.

VI. SEALING.

Apart from the two solenoid-controlled valves for switching in and out, which need not, necessarily, be considered as parts of the breaker proper, there is, only, one valve the sealing of which must be perfect:— this is the air-blast valve. This is a simple and easily accessible valve-seat sealing such as has been universally used for decades. The compressed air pressure in the cylinder acts itself so as to create the tightness pressure of the valve seat, so that alterations in the elasticity of the material used is of no significance. Thus, the sealing of the breakers is, practically, perfect. All the other sealings are only under compressed-air pressure during the opening of the breaker that is to say during a few hundredth parts of a second, and, therefore, have no influence on the sealing quality of the apparatus.





Figs. 6 and 7. — Brown Boveri air-blast high-speed circuit breakers, in vertical and horizontal design with built-on over-current series relays.
Rated voltage 11 kV. Rated current 400 A. Rupturing capacity 100 MVA.

In connection with this question, the tests on air tightness as carried out in the plant according to Fig. 5, are worthy of note. The pressure loss measured of the whole plant—all connecting cocks being open—was 0·25 kg/cm^2 over a period of 24 hours. In order to grasp the significance of this fact, it should be pointed out that the test allows of estimating how long the plant can be left in this state without the compressed-air generator having to start pumping. Allowing for no switching operations being carried out, the plant can hold out for 26 days.

VII. POSITION INDICATOR.

The organ which indicates whether the breaker is open or closed is mechanically connected to the breaker shaft driving the disconnecting contacts. It is, therefore, forcibly interlocked with the latter and does not simply work in function of the movement of the control organs. There can, thus, be no faulty indication of position:— further, the position of the disconnecting contacts, themselves, is clearly visible.

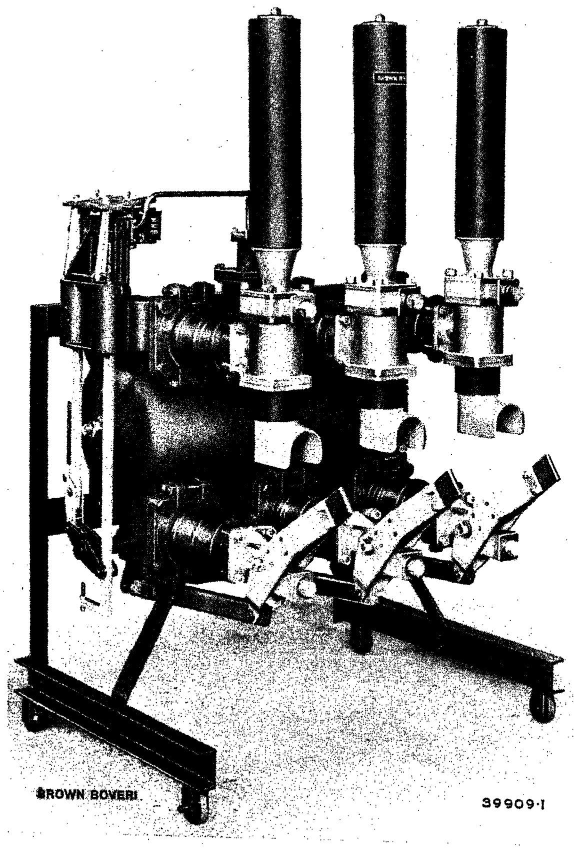


Fig. 8. — Brown Boveri air-blast high-speed circuit breaker, vertical design with truck for running out.
Rated voltage . . . . 24 kV.
Rated current . . . . 1000 A.
Rupturing capacity . . 500 MVA.

When the breaker is open they show an unmistakable break in the circuit. This property which gives a high degree of safety and allows easy supervision is important and will be immediately appreciated by service engineers so that it is unnecessary to say more about it.

VIII. CONTROL.

Control is of the simplest nature. In the majority of cases, the two control valves will each be equipped with a small solenoid to allow of governing them from some control room. The control switches can be of the simplest kind, namely two independent push buttons. The two interlocks, mentioned at the beginning of this article, prevent any imaginable faulty switching operations such as occur, chiefly, when faulty or incomplete control impulses are imparted to the breakers, owing to human error. The breakers can also be controlled by hand. A manometer on each breaker shows the operators the pressure prevailing in the tank.

A special feature of these breakers is the tripping gear by protective relays. A power-storage (spring-operated) apparatus is the principal organ of this gear which is so mechanically coupled to the driving rod that it is loaded by the closing movement. Thus the power required to trip the breaker is always stored up ready when the breaker is closed and the protective relays have only got to provide the very small amount of power to release the catch of the power-storage gear. Thus, these breakers are suitable both for mechanical tripping by built-on over-current relays (Figs. 6 and 7) and for tripping by secondary relays such as over-current, minimum-voltage, selective relays, etc., as well as for tripping by current transformers.

IX. ATTENDANCE.

No particular attendance is necessary with these breakers. On account of the very quick extinguishing of the arc, the contacts are far less stressed, even under short-circuit rupturing, than is the case for oil or water circuit breakers. The air-blast high-speed circuit breaker shows a minimum wear of contacts. Inspection of contacts and possible replacement of burnt pieces is, therefore, only necessary after very heavy short-circuit rupturings. It is easy to get at the contacts for purposes of inspection etc. and this only takes a few minutes. No special attention need be paid to the lubrication of the breaker; the moving parts can be treated like similar parts of any piece of machinery.

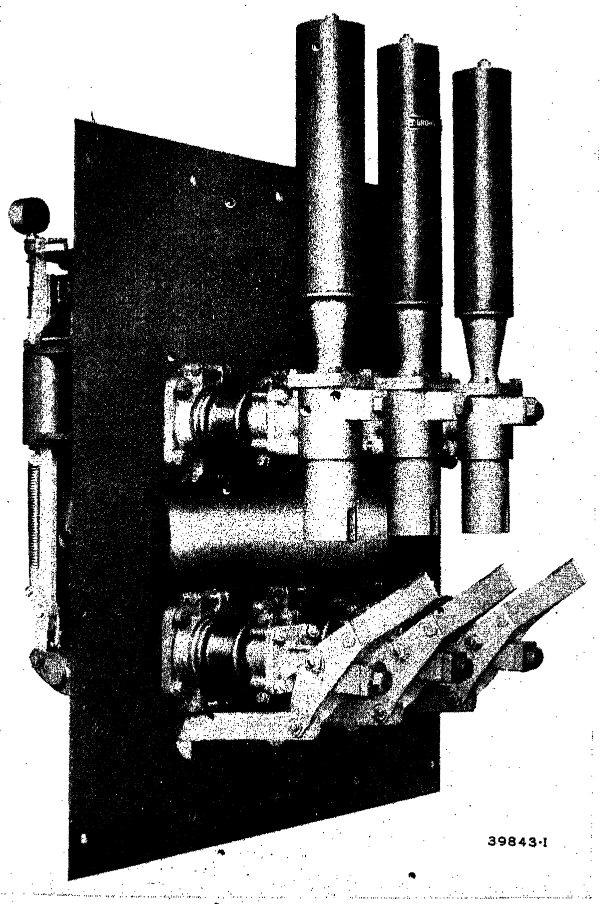
X. ARRANGEMENT OF THE BREAKER IN THE PLANT.

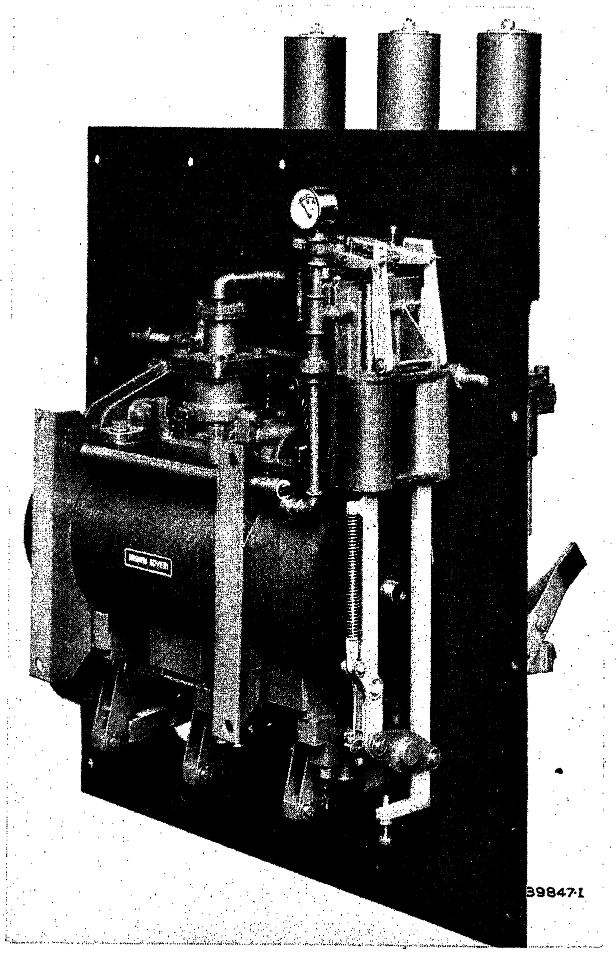
In developing these new breakers, special attention was given to the important question of how they would be mounted in the switchgear plant and of how they could be put in in the place of older oil circuit breakers. The principle adhered to was that in laying out a switchgear plant and in designing the leads, it should no longer be necessary to subordinate the arrangement of the plant to fixed breaker designs such as in the case when oil or water circuit breakers are used. Thus, it should be possible to lay out a new switchgear plant on whatever lines appear most suitable to the services it has to perform, without any regard for the shape of the breakers going into the said plant. Thus, if the demands made on the existing oil circuit breakers of a given plant exceed the limits of safety so that it is desirable to replace them by the more efficient air-blast quick-acting breakers, this can be done without expensive alterations of the plant itself, because the design proper of the new breakers can always be chosen to suit the conditions of the plant under consideration. Terminal connections are on the fulcrums of the three disconnecting contacts, on the one hand, and on the three arcing chambers, on the other.

Fig. 6 shows the breaker placed vertically, for mounting on a wall, with three connections above and three below. This arrangement is chosen when the breaker is to be inserted on the lineal layout of the leads and when the existing building makes this design seem the most advantageous. If the arrangement of the breaker on a truck seems the better one, it can be mounted on a truck frame as shown in Fig. 8.

Fig. 7 shows the breaker put up horizontally, all six connections being above. This arrangement with or without rollers, is chiefly used when it is a question of replacing older breakers by new air-blast high-speed breakers of greater rupturing capacity.

The design of the air-blast high-speed circuit breakers has been so thoroughly studied that provision





Figs. 9 and 10. — Brown Boveri air-blast high-speed circuit breakers, with partition plate, seen from the high-voltage side and from the drive side.
Rated voltage 11 kV. Rated current 400 A. Rupturing capacity 250 MVA.

has been made for putting a partition between the high-voltage parts and the air tank and control apparatus, in the manner shown in Figs. 9 and 10. This design is of great importance in new plants, It allows of designing the switchgear plant on quite

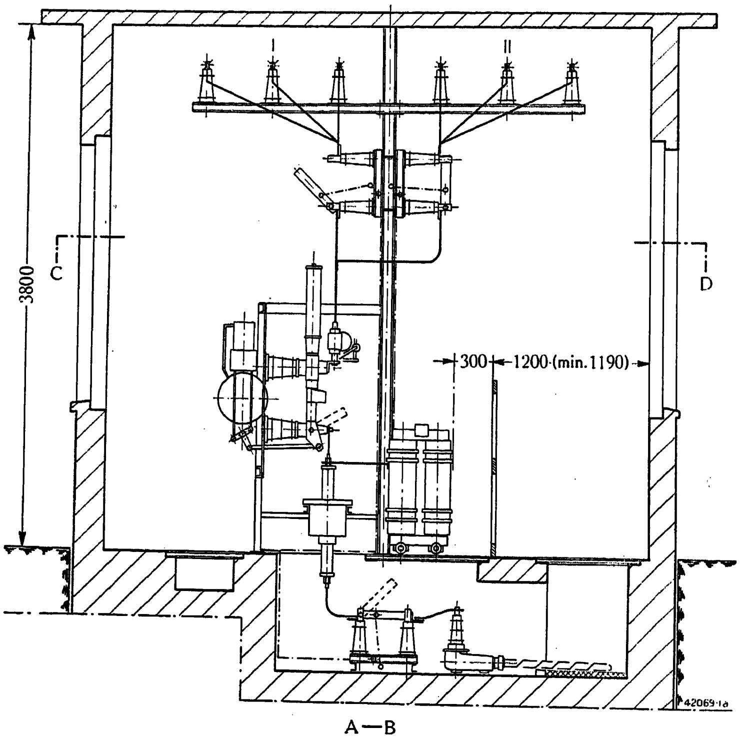


Fig. 11. — Section through a switchgear plant with a double system of bus-bars and measurement apparatus, equipped with Brown Boveri air-blast high-speed circuit breakers.

Rated voltage . . . . 24 kV.
Rated current . . . . 640 A.
Rupturing capacity . . 500 MVA.

new lines. As these breakers are free from the danger of explosions, fire or noxious gases, there is no reason for subdividing into cells the outgoing leads of the plant by means of rigid partition walls. It is, thus possible, to pass from the cell design of building to the hall design with all its advantages of better supervision and lower building costs. Further, it is no longer necessary to have front panels to mount the apparatus, as simple frames of sectional steel are sufficient and improve visibility. Fig. 11 gives a section through a switchgear plant with double bus-bars and measuring apparatus, equipped with air-blast high-speed circuit breakers for 24 kV and 500 MVA. The space taken up is very small and the building costs very low and yet the layout of the leads is both simple and easy to supervise. The separating partition between the high-voltage part and the other parts of the breaker give complete protection against accidental contact with live parts while making the driving side and compressed-air pipes accessible at all times. The high-voltage side of the breaker, as well, can easily be got at for inspection, after first drawing back the voltage transformer without oil filling and after putting in two portable partition walls to shut off the breaker being inspected from the neighbouring outgoing leads, this without it being necessary to take the breaker out of position. From the front side, there is no partition to block the view and the open or closed position of all the breakers can be ascertained at a glance from the position of the disconnecting contacts, ranged in a line.

The design with partition built in is very suitable indeed for iron-clad switchgear. Fig. 12 shows the arrangement of the breaker in a panel which can be run out. The plate concides with the front wall of the panel. The driving side is always accessible and requirements made on a plant of this type such as absolute protection against contact with live parts, isolation from foreign influences and compactness are all met in the most complete manner. Iron-clad switchgear panels without any massive fillings equipped with air-blast high-speed circuit breakers take up less room than any other design and are absolutely fire and explosion proof.

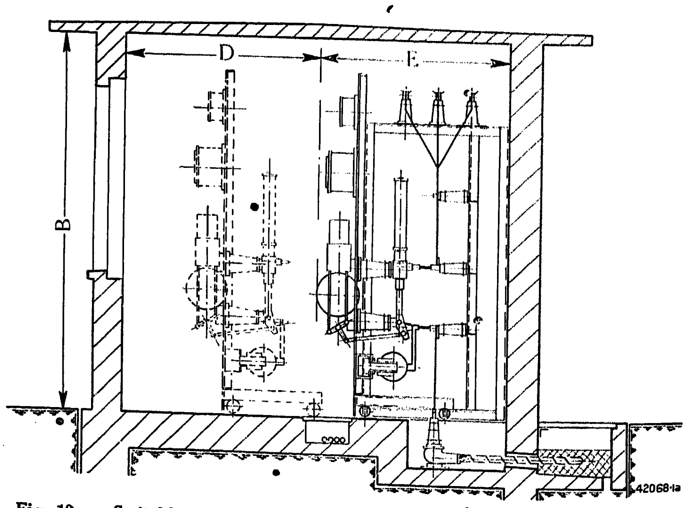


Fig. 12. — Switchboard panel for voltages up to 11 kV equipped with Brown Boveri air-blast high-speed circuit breakers, plant without massive filling, of armoured type and of truck design for running out.

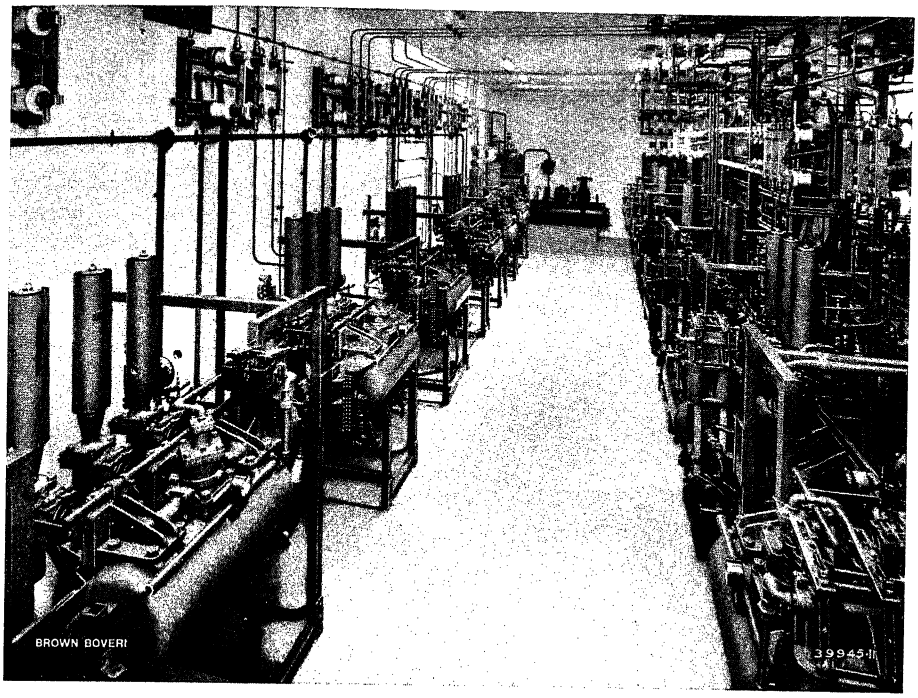


Fig. 13. — Electricity Works of the Town of Winterthur, 3·3-kV switchgear with 12 Brown Boveri air-blast high-speed circuit breakers.

is exempt from the danger of surge voltages arising, because the arc always extinguishes, as in other breakers, as the current wave passes through zero. Its simple design with visible disconnecting contacts make it a favorite with plant operators. As there is only one valve which plays a part in the sealing, the tightness of the breaker is of a high order and meets the most stringent requirements. The breaker uses little compressed air and, practically, requires no attendance as the wear of the contacts is extremely slight. The noise made at opening under rated load is, practically, the same as with other types of breakers and, in any case, much less than with D. C. quick-acting breakers. The choice of designs and elimination of the danger of explosions, fires and noxious gases simplify the designing of the switchgear plant. They also simplify erection and building and make for great reliability.

XI. SUMMARY.

The new Brown Boveri air-blast high-speed circuit breaker is an apparatus which fulfills every possible conditions which can be imposed on a modern breaker. It is a high-speed breaker in the true sense of the word and, while completely fulfilling the justifiable demands for quick switching, it

(MS 951) *W. Walty. (Mo.)*

THE VARIABLE SPEED DRIVE OF RING-SPINNING FRAMES AND DOUBLING FRAMES BY THREE-PHASE SHUNT COMMUTATOR MOTORS.

Decimal index 631.34 : 677.052.3.

TO Electrotechnology must be given the credit of having introduced improvements in the mode of operation of ring-spinning machines and of having brought this most essential agent in yarn production to a higher degree of perfection. Contrary to the mode of operation of the self-acting mule, spinning and winding are continuous and simultaneous operations on the ring-spinning machine. This constitutes an economic superiority for the latter, but has a certain disadvantage as regards the spinning process itself. The conditions requisite for spinning and winding are not entirely fulfilled. The very wide fluctuations in the tension of the thread, when spinning at constant speed, affect its quality and set a limit to the working speed, which prevents the full productive capacity of the machine, from being, even, approached.

By equalizing the tension of the thread, through varying the spinning speed, the working process can be considerably improved. This was the principle which Brown Boveri followed in 1907/8[1] after very thorough investigations had been carried out on the characteristic of the thread tension during the spinning process and they made known the law according to which the speed

[1] The first Brown Boveri patent on an automatic spinning regulator and the first delivery of single-phase commutator motors with variable speed, in Deri connection, for ring-spinning frames, date back to as early as the year 1905.

must be changed in order to get a better yarn with constant thread tension while, at the same time, benefitting from the greatest production the machine is able to give.

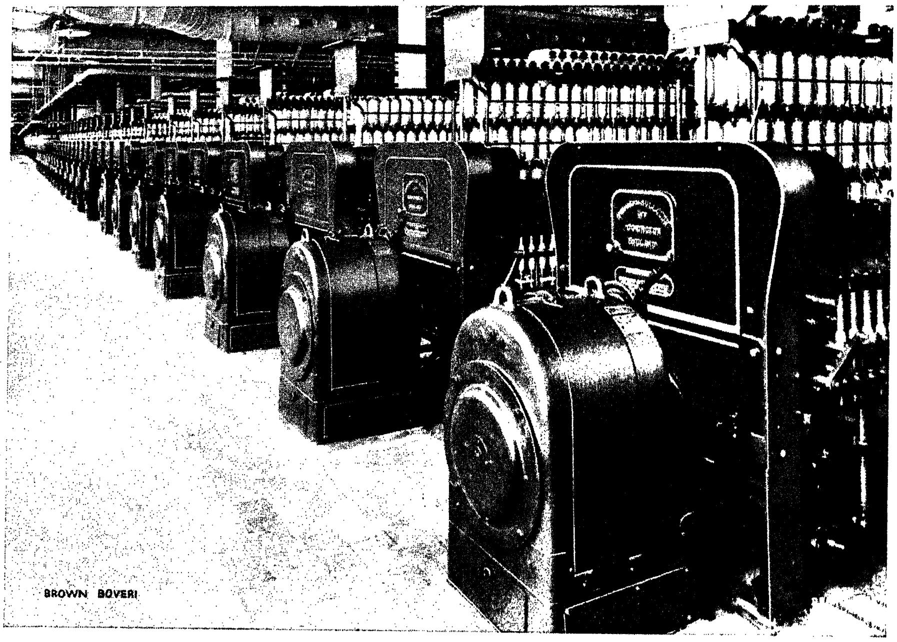


Fig. 1. — Cotton ring-spinning machines with three-phase *shunt* commutator motors Type PND and spinning regulator.

The characteristic spinning diagram (Figs. 2a and 2b) shows the close and periodic regulation of speed which is called for during one doffing, a regulation which the machine, itself, must control. At that time (1907/8), the application of this principle meant introducing quite novel methods of regulation. This led to the design of special spinning motors, namely:— direct-coupled A. C. commutator motors, totally enclosed, built especially for this purpose and having smooth speed regulation over a wide range, by means of simple brush displacement and without losses; it also led to the design of the spinning regulator which transmits the movements of the ring plate to the motor brush rocker and regulates the speed of the motor according to the formation of the cop. Drives of this type allowed of a highly successful practical application of the theories put forward. The driving method in question shows a number of advantages, namely:— easy adjustability of spinning speed to yarn number and to the quality of raw material used, setting of the most advantageous working speed during a doffing, whereby, to reduce the number of thread breakages, the cop bottom can be spun at reduced speed and more than two thirds of the bobbin at a considerably higher speed than is possible with transmission-shaft drive or constant-speed motor drive. This *basic regulation*, alone, either by hand or by means of the spinning regulator, increases the output, while the additional *periodic regulation* by the spinning regulator allows, apart from a still greater average working speed, an approximate compensation of the thread tensions on the drawing cylinder and bobbin. An evenly distributed and increased strength is imparted to the thread, the bobbin is uniformely firm and carries more yarn for its size. Thanks to the compensated thread tension, quite fine, soft yarn can be manufactured on the ring-spinning machine instead of on the self-acting mule. More than 10,000 Brown Boveri A.C. commutator motors with speed regulation are driving many millions of spindles in all the textile countries in the world. Most of these motors have a series characteristic. Their extensive use proves that they meet the requirements asked from them.

Despite the progress made, development work goes on. It was shown that it would be of still greater advantage if even the small speed fluctuations which are felt slightly by motors of series characteristic, when

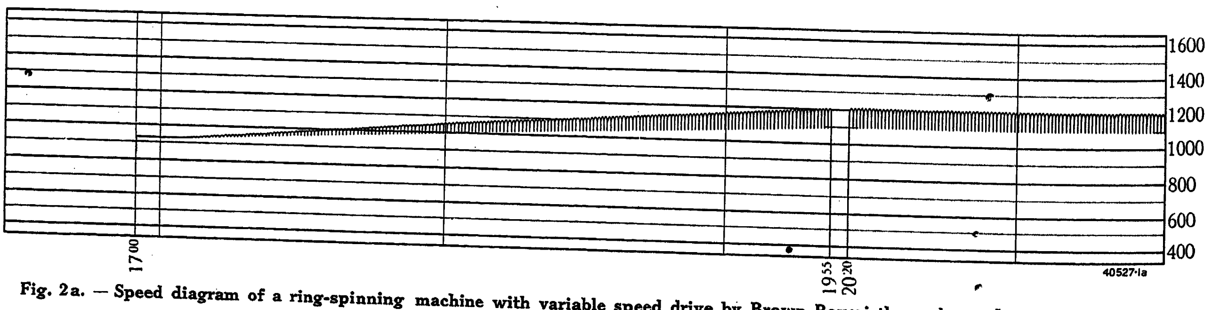
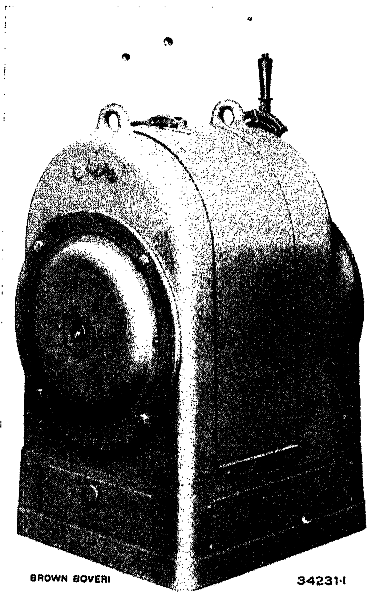


Fig. 2a. — Speed diagram of a ring-spinning machine with variable speed drive by Brown Boveri three-phase *shunt* spinning motor, spinning yarn number 70 engl.

voltage or load changes occur, could be eliminated and the most favourable speeds, which had been fixed by experience, could be held to almost exactly. Such extreme conditions of stability can only be met by a drive equipped with motors having a shunt characteristic. The new Brown Boveri three-phase *shunt* commutator motor with Schrage connections fulfills the severest conditions in every way (Figs. 2 and 3). The machine on which diagram 1 was recorded is driven by a *shunt* spinning motor of this kind. The diagram illustrates conditions which are those demanded of ideal spinning. The position of the commutator brushes, alone dictates, at each moment, the speed. *Fluctuations in load,* or *variations in the supply voltage* exercise *no influence.* Therefore, when the bobbin is increasing and in the morning when the machine is cold there is no *drop in speed.* The motor maintains the peed set to, exactly and continuously. The automatic etting by the spinning regulator is not affected by ny influence and rigidly exact control of working onditions is imposed, even with mills working in shifts. he advantages of drive at variable speed are fully itilized and the shunt motor is gradually superseding he series motor, of which it retains all the advanages, but to which it is superior in regulating qualiies, so that it can be expected to remain master of ie field.



ig. 3. — Three-phase *shunt* commutator notor (ring-spinning motor) Type PND, seen from non-driving side.

A very valuable quality of the Brown Boveri *shunt* pinning motor is its restricted length, a result attained by using a special design of rotor, protected by patents. These motors can, therefore, be installed in very restricted quarters; they hardly take up more room than line-shaft drive. In other respects, they are admirably adapted to spinning-mill conditions, their chief characteristics being:— totally-enclosed, pipe-ventilated design, to be connected up to air ducts; smooth outer surfaces to prevent the collection of dust, roller bearings with grease fillings to last as long as two years; the simple brush-shifting device allowing of close setting by hand or by automatic regulation, with very clear scale. The switch for connecting the motor to the supply is also built into the motor and interlocked with the brush-shifting gear. No starter etc. is required; starting, regulating and stopping is done by means of the brush-shifting handle. Service is, therefore, extremely simple and connection to the supply system is by three terminals as with ordinary induction motors. The efficiency at synchronous speed is as high as with belt drive by ordinary induction motors at constant speed while the power factor improves up to 1 for speeds above synchronism. These motors are, therefore, economical to operate and are suitable for improving the total power factor of spinning mills.

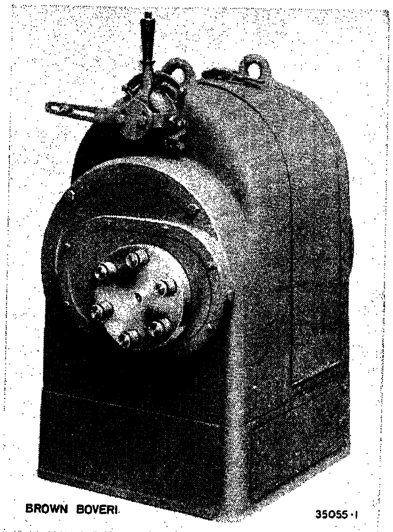
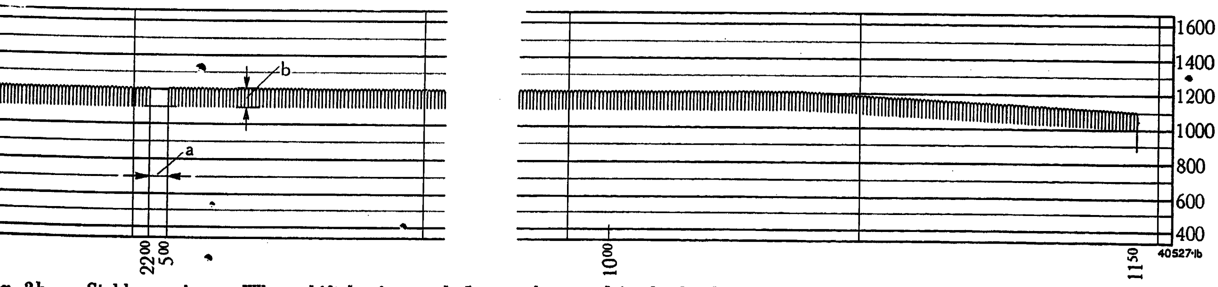


Fig. 4. — Three-phase *shunt* commutator motor (ring-spinning motor) Type PNDZ with built-in reduction gear, for hand-regulation and regulation by a spinning regulator.

The motors are built in various sizes, for outputs of 3 to 16 kW and for regulating ranges of 1 : 2 and 1 : 3 or more; they are designed so as to be suitable for every kind of spinning and doubling frames. *Cotton-spinning frame drives* are characterized by direct-coupling of one single motor; *worsted-yarn spinning frames*



g. 2b. — Stable service:— When shift begins work 5 a. m. the speed is absolutely the same as when work was stopped the night before at 10 p. m. (a). Even periodic regulation (b).

are equipped with double drives, composed of two motors, each of which drives one side of the machine independently of the other. Owing to the low operating speed, motors to drive worsted-yarn spinning frames are designed with high-grade, oil-immersed reduction gears, built into the bearing shield. The design with a reduction gear is also suitable for the drive of *bast-fibre* flyer spinning and doubling frames. A spinning regulator is, usually, not used, here, but drives which can be regulated, as in the case of ring-doubling frames, are of great importance; the reason is that adaption to the most favourable speed for the different yarn numbers and doubling effects and readjustment by hand during spinning or doubling has been proved, in practice, to have many spinning and economic advantages.

The advantages of the variable speed drive of ring spinning frames and doubling frames by three-phase *shunt* commutator motors can be summarized as follows:— the r.p.m. and the spinning speed remain stable even under fluctuations in the load or in the supply voltage. For average and fine yarn numbers the spinning speed can be automatically governed by the formation of the cop, in such a way that the thread tension is compensated for and the winding of the bobbin is improved. Although the spinning speed is greater, there are fewer thread breakages. The machine produces more and better yarn. Quite fine yarn up to the very finest yarn, of even and soft quality, can be spun on the cheaper and simple ring-spinning frame instead of on expensive self-acting mules which take up so much room.

Numerous plants with ring-spinning frames and doubling frames equipped with the variable-speed drive by Brown Boveri *shunt* commutator motors have been running for years in very efficient mills; they have the further advantage of requiring hardly any attendance and consuming very little current. These drives have entirely fulfilled the high expectations aroused by them. No mill should put off making use of the multiple advantages which these variable speed drives offer, as they raise to a maximum the production of existing machinery and the quality of the yarn produced on them.

(MS 918) *H. Wildhaber. (Mo.)*

NEW DIESEL-ELECTRIC DRIVES OF BROWN BOVERI DESIGN, FOR SHIPS.

(Continued from No. 9/1935.)

Decimal index 621. 34. 033. 44: 629. 12.

II. *The Norwegian mine layer "Olav Tryggvason".*

As is generally known, a distinction is made on warships between economical or cruising speed and full maximum speed. The cruising speed is the one most used and the chief condition inherent thereto must be great economy in fuel consumption. Full speed with the engines at maximum load is only used occasionally and specific fuel consumption is, therefore, of less importance here than low weight per shaft horse power (S. H. P.). A combined driving plant is the best suited to meet these dual conditions, that is to say steam-turbine drive for highest speed and Diesel engines as a complementary drive for cruising speed, the latter with electric transmission of power to the propeller shaft, for reasons which will be explained later.

The use of Diesel engines for cruising gives the most economical fuel consumption but the weight of the machinery per shaft horse power is relatively heavy. The steam plant, on the contrary, is light and takes up little room, but fuel consumption is greater than with Diesel-engine drive.

The Norwegian mine layer "Olav Tryggvason" (see Fig. 32, page 13 of The Brown Boveri Review, January/February 1935), used in times of peace as a training ship and which was commissioned in the spring of 1934, is equipped with a combined drive of this kind. Fig. 7 shows the S. H. P. / speed diagram referred to one propeller shaft. For a cruising speed of 14 knots, an engine output of $2 \times 700 = 1400$ S. H. P. at 190 r. p. m. suffices and for maximum speed of 20 knots an output of $2 \times 3000 = 6000$ S. H. P. at 315 r. p. m. is required.

The following are the special problems which must be solved when planning a combined engine plant of this type:—

1. The most practical layout of the Diesel engines in the engine room and the best system of transmission of their output to the propeller shaft the position of which is determined by that of the main driving engines, which are geared steam turbines in the case under consideration.
2. The governing of the output of the Diesel engines when they work together with the steam-turbine plant, in such a manner, as shown in Fig. 7, that the Diesel engines run at nearly their full output at all speeds superior to cruising speed, whatever may be the variations in the speed of the propeller. The setting of the propeller speed is to be carried out from the steam-turbine side alone, so that the Diesel engines have to adapt themselves automatically to the new speed conditions.

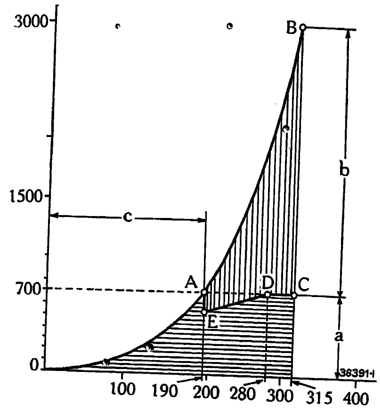


Fig. 7. — Output Speed (r. p. m.) diagram of the mixed driving plant of the mine layer "Olav Tryggvason".

Ordinates: Output in S. H. P. per propeller shaft.
Abscissae: Speed of propeller in r. p. m.

a. Output of Diesel-electric cruising plant.
b. Output of steam-turbine plant.
c. Range of cruising speed.

This condition can only be fulfilled satisfactorily by *electric* power transmission of the Diesel output to the propeller shaft and by using D. C., the reasons for this being:—

1. Electric transmission allows of mounting the Diesel-engines in the most suitable position from the point of view of the available space and from that of attendance, quite independently of the propeller shaft. It is practically impossible to place the Diesel engines directly in the line of the propeller shaft. An electric motor, on the contrary, can easily be mounted on the propeller-shaft line or flange connected to an intermediate shaft of the turbine gearing.

2. With D. C. as opposed to A. C., it is electrically possible to carry out not only changes in the sense of rotation but also smooth adjustments of the speed ratio between Diesel engine and propeller motor, during service, so that the Diesel engines can work constantly with the same speed and in the same sense of rotation and only the propeller motors have to be adjusted to the momentary speed desired for the propeller shaft.

Fig. 8 shows the general layout of the engine room plant of this vessel [1]. The text attached to the illustration gives all data of value both on the vessel and on the engine-room layout.

Fig. 9 shows a propeller motor during shop tests.

The Diesel-electric machine plant was called on to fulfill the following special conditions:—

1. Drive of both propeller shafts at all speeds, from 0 up to $\pm$ 190 r. p. m.

[1] These and the other illustrations and technical data have been taken from the following detailed articles published on the subject: — "Olav Tryggvason", Marinens nye minelegger og øvelsesskib av ing. Fladmark in the January number 1934 of the Norsk Tidskrift for Sjøvesen and Minenleggeren "Olav Tryggvason"s elektriske anlegg av Marinens elektro ing. B. M. Huseby in Elektroteknisk Tidskrift No. 16, June 1934.

2. It must be possible to regulate and reverse the propeller motors independently of one another; reversing time 20 seconds.

3. It must be possible to control the propeller motors from the bridge as well as from the rear engine room and, finally, from the main switchboard, as well.

4. The propeller motors must each deliver an additional output of 700 H. P. to the propeller shaft on the whole speed range, from the 190-r. p. m. cruising speed to the 315-r. p. m. full speed, this in collaboration with the steam plant; all manœuvring between 190 and 315 r. p. m. being carried out by the steam plant.

On the subject of the choice of the regulating system, Mr. B. M. Huseby says in his article mentioned in the foot note:— "Only D. C. could be taken into consideration. The problem was to decide which of the various D. C. systems was the most suitable. Careful study of the matter showed that ordinary Ward-Leonard connections would not meet the requirements. The two other available systems, namely the constant current system and the Brown Boveri system both fulfilled all the requirements, but as the latter was the more economical, it was chosen. We are pleased to be able to testify, here, that the firm in question, working through its Norwegian concessionaries, was able to meet sucessfully the competition of other firms and to carry out the manufacturing work in the country itself."

The diagram of connections of the electric plant is reproduced in Fig. 10. In the paddle steamer "Genève" speed regulation is effected by changing the excitation of the main dynamo (Ward-Leonard connection) while, in the present case, the field of the propulsion motor itself is regulated by means of a potentiometer in order to attain the speed and sense of rotation required. The excitation of the main dynamo, as is shown, is influenced by an automatic quick-acting Brown Boveri regulator; this works as a current regulator and is inserted on the field circuit of the exciter dynamo. The regulators do not, however, work to produce a constant main current alone but an additional factor of voltage dependency is introduced so that, for low propeller speeds, the main current is also reduced by the regulators. Thus, at low speeds, there are lower electrical losses and the plant is more economical than one working to constant current.

When the Diesel generator is running under no load, that is to say when the propeller shaft is stopped, there is a current of about 1000 A in the main circuit. As the potentiometers are still in the zero

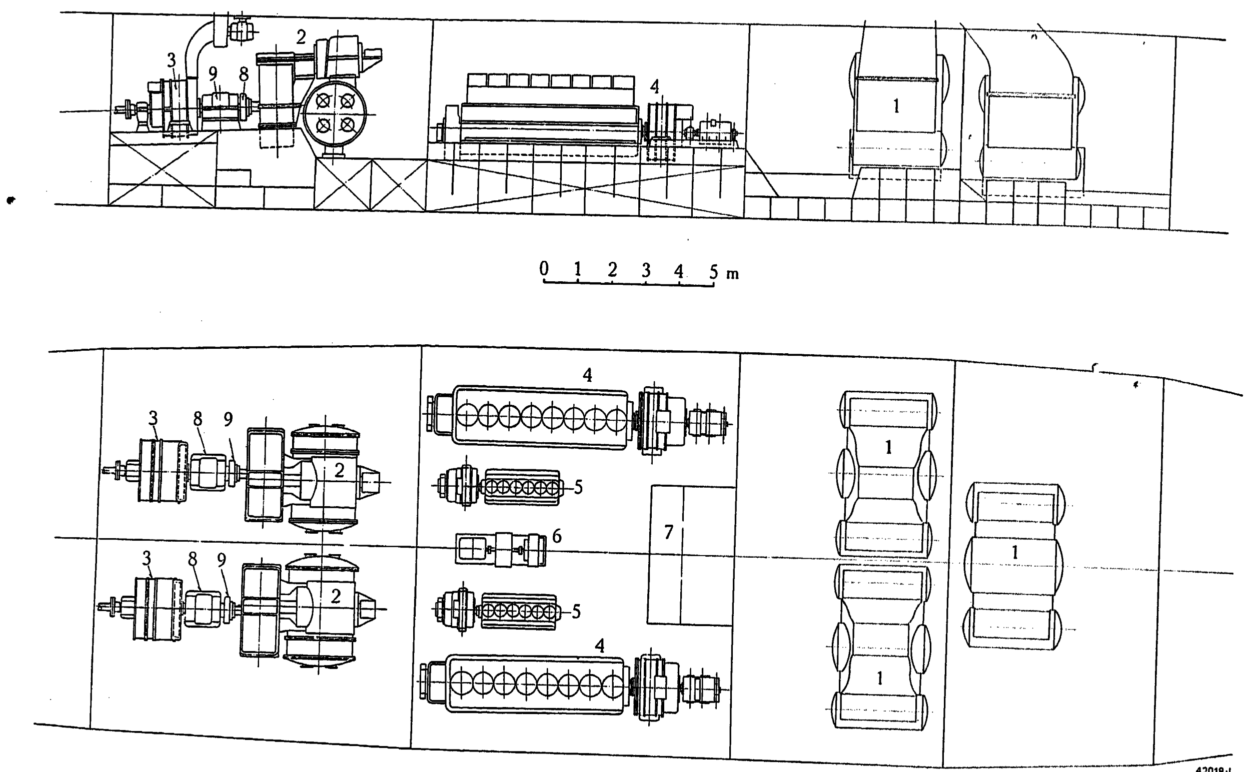


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Fig. 8. — Diagrammatic layout of the machine plant on the mine layer "Olav Tryggvason".

1. Water-tube boiler, oil fired, 21 kg/cm² abs.
2. Geared turbines each 2300 S. H. P., 315 r. p. m.
3. Propeller motors each 700 S. H. P., 250 V, 190 r. p. m.
4. Main Diesel dynamos with built-on exciters. Four-stroke cycle, eight-cylinder Diesel engines of Sulzer design, each of 850 B. H. P., 530 r. p. m., direct coupled to a Brown Boveri dynamo of 560 kW, 250 V and to an excitation dynamo of 16 kW, 230 V.
5. Two auxiliary dynamos each 120 kW, 230 V, 530 r. p. m.
6. One auxiliary Diesel-driven dynamo set MAN-Diesel engine 40 B. H. P. coupled to a 16-kW dynamo, 230 V and to one 11-kW dynamo, 115 V.
7. Manœuvring switchboard.
8. Propeller thrust bearing.
9. Coupling.

Main characteristics of the vessel.

Length B. P.	97·30 m.
Breadth at main framing	11·45 m.
Depth	7·18 m.
Displacement, completely equipped and armed	1924 t.
Corresponding draught	3·6 m
Cruising speed and output	14 knots, 1400 S. H. P. at 190 r. p. m.
Highest speed and output	20 knots, 6000 S. H. P. at 315 r. p. m.

position, that is to say as the propeller motors are not excited yet, they do not produce any torque. The propeller shafts only begin to rotate after the potentiometer has been moved from the zero position, in either sense of travel.

On the whole range of cruising speeds, that is to say up to 190 r. p. m. the speed is adjusted by the potentiometer alone. Contrary to what occurs with ordinary D. C. shunt motors, a weakening of the field produces a slowing down of the r. p. m. and vice versa. Each potentiometer is remote-controlled by a motor, the control can be made from the bridge or from the operating stand of the steam turbines. Further, direct hand control from the main switchboard can also be carried out.

When the turbines work, the remote control of the propeller motors is switched over to the turbine control stand. Before the turbines are switched in, the speed of the propeller motors is slightly lowered by weakening the field (point E in Fig. 7), in every other respect, the potentiometers are left in position. The subsequent r. p. m. regulation is performed by opening and closing the steam manœuvring valves to the turbine. As the speed of the propeller increases, the voltage in the main electric circuit increases as well up to point D (280 r. p. m.) where the voltage and output of the Diesel-electric plant reaches 100 %. From D to C the voltage still increases up to about 106 % but the current decreases to about 94 %, so the output remains the same.

Of course, a combined plant of this nature requires a number of safety measures. Thus, for example, it must be certain that when the vessel is reversed by acting on the turbines, the electric plant is cut out. The main-current circuit is protected by overcurrent and counter-current relays. Thanks to the quick-acting regulator, this plant can be manœuvred so that, whatever the rapidity with which the control

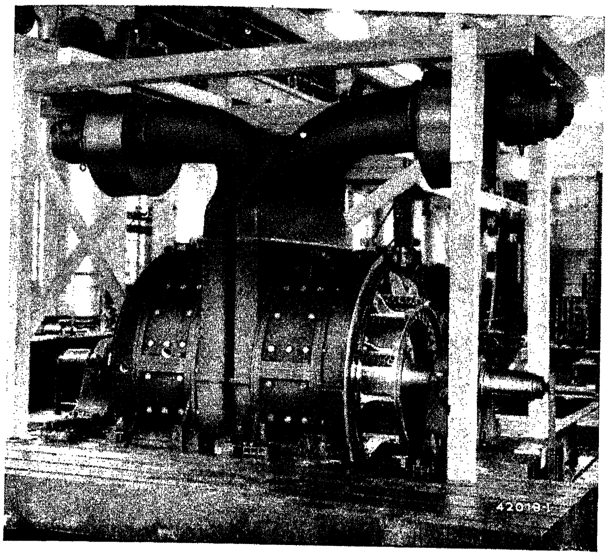


Fig. 9. — Propeller motor of mine layer "Olav Tryggvason", on test bed.

The motors are cooled by fans which draw air from the engine room through the said motors and expell it outboard.

system in use up till to-day could be found than the following imaginary one :—

A motor-car driver, in the midst of dense traffic, is deprived of direct control of steering wheel, gears and brake and must control his car indirectly, by giving orders as to speed and direction, to some mechanic, who has then to carry them out.

In harbour craft, coastal vessels and ferry boats, control from the bridge increases safety and the speed with which manœuvring can be effected, while in all other types of vessel, as well, the possibility of being able to control the movements of the ship from the bridge, at entering ports, for example or coming alongside quays and in cases of danger is of incalculable, advantage. As an argument against control from the bridge, it has often been said that the captain and the personel on the bridge are there for purposes of navigation and have no specialized knowledge allowing them to deal with electric control apparatus

lever of the potentiometer is thrown over, no overloading of the electrical machinery or of the Diesel engines occurs.

The entire electric plant was built in the work-shops of the Norsk Elektrisk & Brown Boveri, Oslo. Apart from the main motors, this firm delivered all auxiliary electric drives for this vessel in so far as they were not special built-on motors, their complete delivery comprising 54 electric machines.

III. *General considerations on the control of Diesel-electric ship drives and on the field of application of the Brown Boveri quick-acting regulator to drives of this kind.*

In electric drive of propeller or paddle-wheel shafts of vessels, the possibility of controlling the vessel from the bridge should be made as much use of, as possible, and this applies particularly to small or medium-sized craft, while manœuvring from the engine room, in general use up till to-day, should be retained, as a spare. The commanding officer, thus, has his vessel entirely under his own hand and is no longer dependent on the reliability of third persons. No better parallel to the

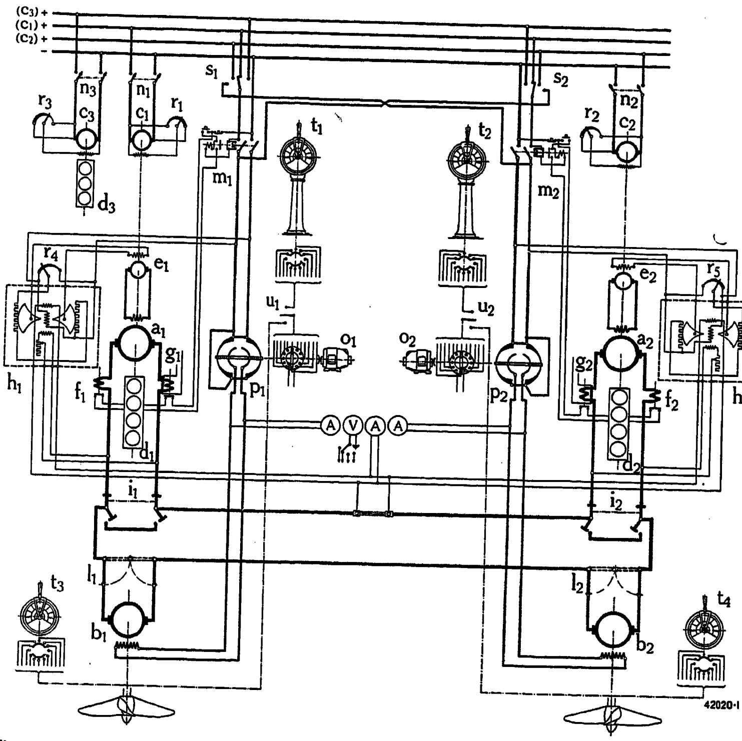
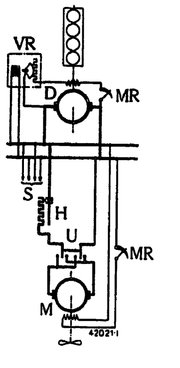
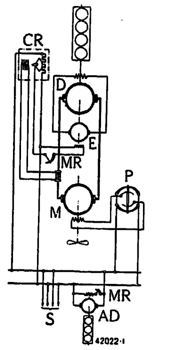
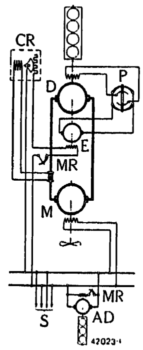
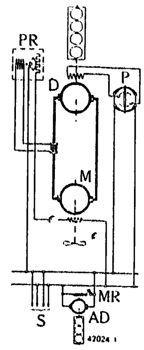
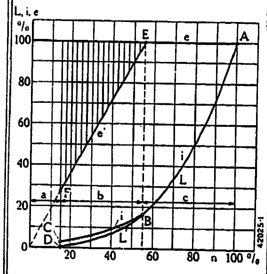
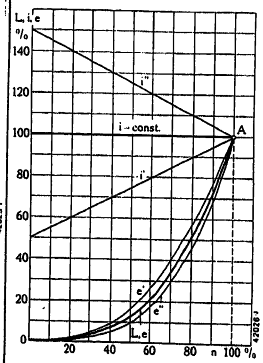
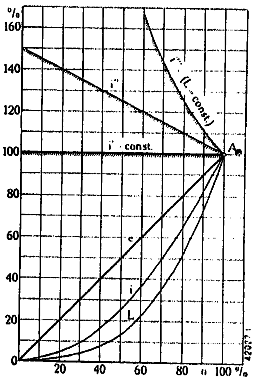
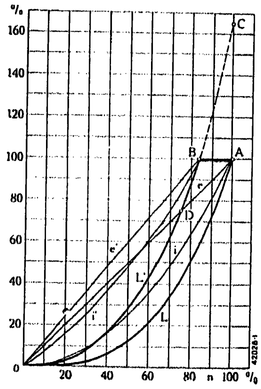


Fig. 10. — Diagram of connections of the Diesel-electric cruising plant of the mine layer "Olav Tryggvason".

- a_1, a_2. Main dynamos.
- b_1, b_2. Propeller motors.
- c_1, c_2, c_3. Auxiliary dynamos.
- d_1, d_2. Main Diesel engines.
- d_3. Auxiliary Diesel engines.
- e_1, e_2. Excitation dynamos.
- f_1, f_2. Over-current-limiting relays.
- g_1, g_2. Reverse-current relays.
- h_1, h_2. Current regulators.
- i_1, i_2. Change-over switches.
- l_1, l_2. Disconnecting links.
- m_1, m_2. Excitation switches.
- n_1, n_2, n_3. Main circuit breakers with over-current tripping.
- o_1, o_2. Remote control by motor of the potentiometers.
- p_1, p_2. Potentiometers.
- r_1, r_2, r_3. Field rheostats.
- r_4, r_5. Field rheostats.
- s_1, s_2. Selective switches.
- t_1, t_2. Control posts on the bridge.
- t_3, t_4. Control posts in turbine room.
- u_1, u_2. Change-over switch for remote control of potentiometers.
- A. Ammeter.
- V. Voltmeter.

Application of the Brown Boveri regulator to different systems of Diesel-electric ship drives.

System	1 Constant voltage	2 Constant or controlled current	3 Variable voltage and current (Ward Leonard)	4 Constant output
Diagrammatic system of connections	 **Fig. 11.** D. Main generator. M. Propulsion motor. MR. Field rheostat. VR. Voltage regulator. U. Sense of travel reverser. H. Rheostat of main circuit. S. Branch for lights and auxiliary motors.	 **Fig. 12.** D. Main generator. M. Propulsion motor. E. Exciter. AD. Auxiliary dynamo. CR. Current regulator. P. Potentiometer. S. Branch for lights and auxiliary motors. MR. Field rheostat.	 **Fig. 13.** D. Main generator. M. Propulsion motor. E. Exciter. AD. Auxiliary dynamo. CR. Current limiter. P. Potentiometer. S. Branch for lights and auxiliary motors. MR. Field rheostat.	 **Fig. 14.** D. Main generator. M. Propulsion motor. AD. Auxiliary dynamo. PR. Constant-output regulator for constant tug load. P. Potentiometer. S. Branch for lights and auxiliary motors. MR. Field rheostat.
General character of the output, voltage and current curves in function of the speed of the propeller	 **Fig. 15.** n. Speed of propeller in r. p. m. L. Output on propeller shaft. e. Voltage. e'. Reduced voltage. i. Current. a. Range of non-regulated speed. b. Range of regulation in main circuit. c. Range of regulation in shunt circuit.	 **Fig. 16.**	 **Fig. 17.**	 **Fig. 18.**
		n. Speed of propeller in r. p. m. L. Output on propeller shaft. Fig. 16: e. Voltage variation for i constant. e'. Voltage variation for i' decreasing. e''. Voltage variation for i'' increasing. Fig. 17: i. Current. e. Voltage. i'. Limitation to constant current. i''. Limitation to increasing current. i'''. Current limitation to constant output. Fig. 18: L. Output on propeller shaft without tug load. L'. Output on propeller shaft when under a tug load or in ice. i. e. and i'. e'. Corresponding character of voltage and current.		
Function of quick-acting regulator	**Voltage regulator**; constant voltage at main generator terminals.	**Current regulator**, for constant current i, for decreasing current i', for increasing current i''.	**Current limiter** for constant current i', for increasing current i''.	**Output regulation**; constant tug load (tug duty regulator).
Speed regulation and reversing sense of travel	In main circuit, possibly in shunt circuit (field weakening). Reversing sense of travel by opening and commutation of main circuit (U).	In the excitation circuit of the motor, by means of the potentiometer P.	In the excitation circuit of the generator, by means of the potentiometer P.	In the excitation circuit of the generator, by means of the potentiometer P.
Economic value of regulating system	If speed regulation carried out in the main circuit, it is in rather large steps and wasteful. The apparatus required is relatively heavy and expensive.	Precise regulations in small steps for both senses of rotation without opening the main circuit. Poor efficiency at partial loads with i: Constant, because i^2R is then a constant. Better efficiency with regulation to i'. Apparatus simpler and much cheaper.	**As in system 2** but less wasteful. The current limiter automatically prevents overloading of the electric machines and of the Diesel engines, so that all the advantages of system 2 are enjoyed.	**As in system 3** the output of the Diesel engines is always fully utilized at all tug loads and overloading is always avoided.
Operation when propeller emerges	Very slight rise in the r. p. m.	Considerable rise in the r. p. m.	Very slight rise in the r. p. m.	Very slight rise in the r. p. m.
Number of electric machines	No need of main and auxiliary exciters (unless the excitation power is very high). The main generator is auto-excited and delivers the current for lights and the auxiliary motors; the number of machines is reduced to a minimum.	Auxiliary dynamo and exciter required.	Auxiliary dynamo and exciter required.	Auxiliary dynamo required.
Practical applications	Cranes and floating dredgers having own propulsion machinery; floating power stations and repair shops, that is to say vessels in which speed is of secondary importance.	Special cases (vessels with two shafts with a generating set, mixed plants) see "Olav Tryggvason".	Standard diagram of connections for most drives.	Tugs, ice-breakers.

and machinery. The control of electric ship drives must be fundamentally so designed that the officer commanding the ship has no instruments to observe during manœuvring and is required to give no consideration to the engine plant; as heretofore, he should be able to give his whole attention to the movements of the ship. He must be able to move the control handle regulating the speed and direction of the vessel in exactly the same manner as he moves the engine-room telegraphs, that is to say as rapidly as he wants to, without any fear of overloading the engines. Too quick manœuvring causes sudden increase in current, unless special measures are taken, and this current increase can cause damage to the electrical machines, may cause overloading of the Diesel engine and even bring the latter to a standstill. As the examples of the "Genève" and "Olav Tryggvason" just given have shown, the Brown Boveri quick-acting regulator has proved a very suitable apparatus to solve in simple economical and, above all, reliable fashion, the control problem in ships with electric drive. Its universal field of application is summarily given herewith. Only the Diesel-electric drives with D. C. are taken into account, in this summary, although it should be said that similar possibilities exist for A. C. ship drives [1].

There are, essentially, four transmission systems with D. C., these being:—

1. The system with *constant voltage.*
2. The system with *constant current* or with *regulated current.*
3. The system with *changeable voltage* and *changeable current* (Ward-Leonard system)
4. The system with *regulation to constant load.*

The fundamental connections and applications of the Brown Boveri quick-acting regulator and the chief properties of the four systems just enumerated are shown clearly in the Table on page 214. To this the following details should be added:—

To 1 (Figs. 11 and 15). *Constant voltage system with Brown Boveri voltage regulator.*

This system is used for plants of low output or in vessels where movement is only of secondary importance, such as floating cranes, dredgers, etc. Regulation in the main circuit is fundamentally wastful. This factor should not, however, be over-emphasized because, firstly, losses only occur at low speeds on condition that the motor driving the propeller be regulated by field weakening in its upper range of speed. The losses, therefore, only occur during a short period and are relatively small as the power delivered in this range is, itself, low. Under certain conditions, shunt regulation can be done away with altogether, for the sake of simplicity and all regulation carried out on the main circuit. The speed regulation is in bigger steps than in the two other systems. Regulation down to a standstill is practically impossible (but usually not required) because the main-current rheostat would be too big, theoretically of limitless dimensions for speed zero. Further the way reversing is carried out —by opening and changing over the main-current circuit—is not as attractive a solution as that applied in the two other systems. The main dynamo has auto-excitation and delivers current at a constant voltage maintained invariable automatically by a Brown Boveri quick-acting regulator and utilized both for the propeller motors and for all the other current-consuming devices on the vessel. Connections according to system 1 were used by Brown Boveri for the Diesel-electric driving plant of the fire-extinguishing ship "Santa Barbara" used in Genoa harbour (see The Brown Boveri Review year 1931, page 239).

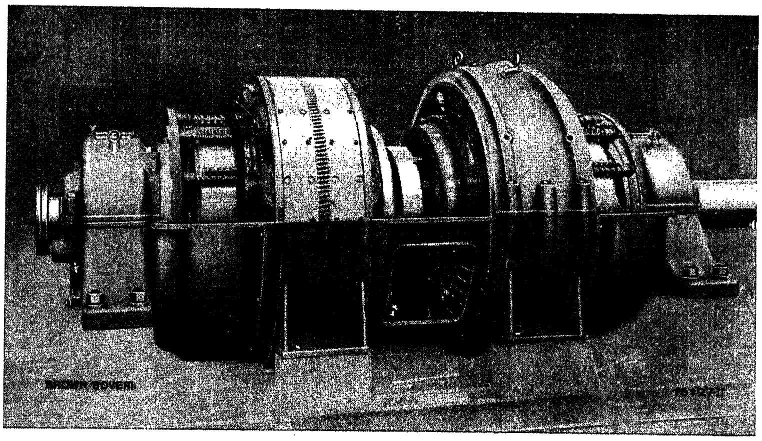


Fig. 19. — Submarine motor, 1300 S. H. P., 270 r. p. m., design with double armature. Each armature half has an auxiliary commutator. When at low speeds (10 S. H. P., 50 r. p. m.) the two main commutators and the two auxiliary commutators are connected in series.

Series-parallel connection of double-commutator or double-armature machines, used by Brown Boveri in many submarine drives, belongs to the constant voltage system, as well (Fig. 19). In this case regulation of the main current is entirely eliminated and the

[1] See The Brown Boveri Review, year 1932, page 148:— Brown Boveri Diesel-electric ship propulsion with alternating current.

place of the main driving steps is taken by series-parallel connection of the different armatures while intermediate steps are adjusted to by weakening or strengthening the field of the motor.

To 2 (Figs. 12 and 16). *Constant current system or controlled-current system with Brown Boveri current regulator.*

In special cases, of which an example was given in section II where the Diesel-electric propulsion plant of the mine layer "Olav Tryggvason" was described, this system [1] offers special advantages. Fundamentally, control with constant current has the disadvantage that, owing to $i^2 \cdot R = \text{constant}$, the efficiency falls as the speed goes down. If regulation is so made that the current falls with the speed, the efficiency is considerably improved but the time required for manœuvring is lengthened because the power available is also reduced, by this measure, when the propeller speed gets low. If, further, several motors are connected in series on the current circuit and if manœuvring is carried out by one motor only, regulation not being to constant current, the speed of the other motors is also influenced. The application of the controlled current system is, therefore, limited to special cases and requires in each careful examination of the most suitable current characteristic to be applied. Generally speaking, the Brown Boveri current regulator allows of using quite standard electric machines, while, if this regulator is not used, machines with very complicated windings or special exciters are necessary, which increase the weight and cost of the plant and lengthen manœuvring times as winding systems of this kind are magnetically inert. The Brown Boveri quick-acting regulator can be said to have no magnetic inertia.

To 3 (Figs. 13 and 17) *Ward Leonard-Brown Boveri system and current-limiting regulator.*

Generally speaking, the classic Ward-Leonard system is to be recommended for Diesel-electric ship drive, as it is not only economical in operation but simple and reliable as well. Speed can be regulated by 100 % in close steps in both senses. When combined with a Brown Boveri quick-acting regulator, working as a current-limiting regulator, this system combines the most important advantages of the system mentioned before, with constant or controlled current, with the advantages of the Ward-Leonard system, and, chiefly that the main current can never attain a value which might endanger the machines, whatever service conditions may arise. When manœuvring rapidly, the current-limiting regulator prevents the electric machines being too highly overloaded and this applies with greater force to the Diesel engine as well. In order not to lengthen manœuvring time unnecessarily, and utilize as fully as possible the power of the Diesel engine during manœuvring, it is advantageous to impart to the current-limiting regulator a characteristic such that at low propeller speeds, that is to say light loads, a bigger current is allowed to flow. An essential character of Brown Boveri current regulator is that its current characteristic in service can be adjusted to suit whatever the actual service conditions may be. In vessels which travel in ice bearing waters (ice breakers, fishing craft for northern waters, etc.) it may happen that the propeller gets jammed by floating blocks of ice. When this happens, the current regulator immediately reduces the current to a value which is not harmful to the electric machines, but which, nevertheless — and this is an important point in ice navigation — does not cut out the propeller motor but, on the contrary, creates a powerful torque so the propeller exercises pressure on the ice and tends to disperse it. An example of the application of the Ward-Leonard system with Brown Boveri current-limiting regulator is that of the paddle vessel "Genève", described under section I.

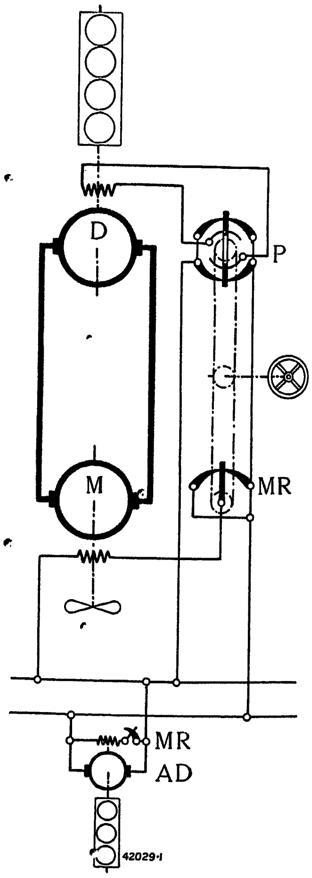


Fig. 20. — Diesel-electric ship drive in Ward-Leonard connection with simultaneous field variations in generator and motor fields in order to reduce cooling losses at low loads (Brown Boveri patent).
D. Dynamo.
M. Propulsion motor.
AD. Auxiliary dynamos.
M. R. Field regulator.
P. Potentiometer.

[1] It should be recalled here that the constant-current system with current generator and current consumer connected in series, is an invention of the Swiss engineer Thury and that all new applications of constant or regulated current are nothing else than developments of Thury's system on which they are based.

Mention should be made here of a special connection patented by Brown Boveri and intended for Diesel-electric ships propulsion according to the Ward-Leonard process. As shown in Fig. 20, both the main dynamo and the propeller motor are, here, provided with field rheostats. Both rheostats are mechanically coupled together so that when the speed drops (fall of generator voltage) the motor field is also reduced and vice versa. This connection has the advantage that no special fan is required to cool the propeller motor. The plant is, thus simplified, made cheaper and economically more advantageous as there are lower field loss and cooling losses.

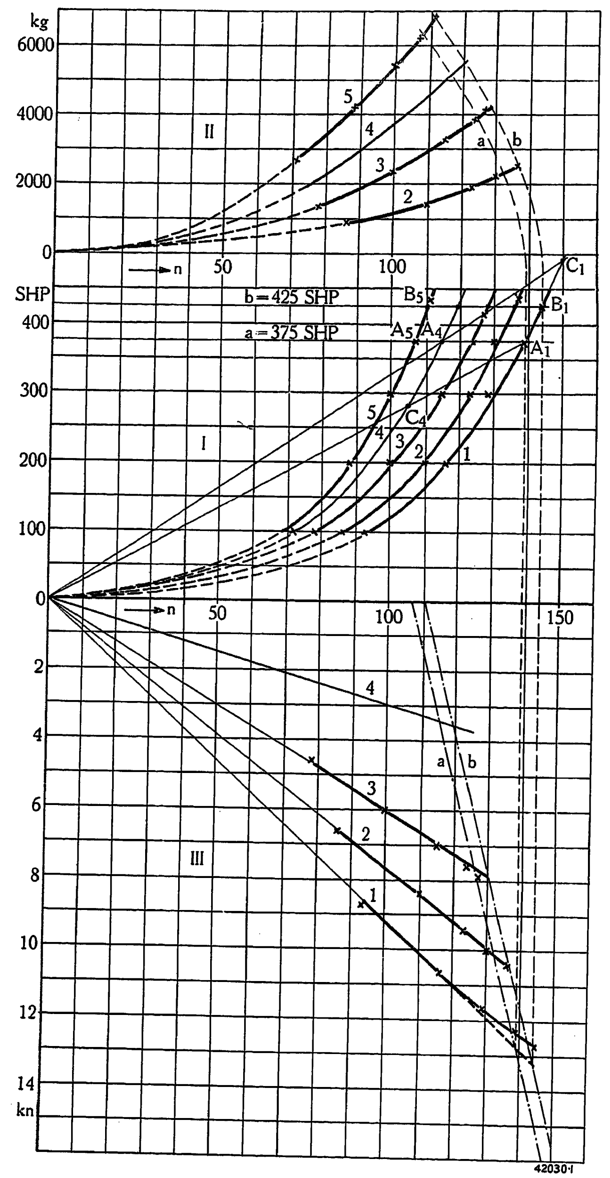
To 4 (Figs. 14 and 18) *Regulation to constant load.*

The question may be raised if regulation to constant load would not be advantageous with system 3, just described, as such a system would make available, constantly, the full output of the Diesel engine for manœuvring purposes and would, apparently, lead to the quickest manœuvring times. However, regulation to constant load on a free navigating vessel, i. e. one without a load in tow, is not practically appliable, on account of the operating characteristics of the propeller and its power-speed curve (as is known, the driving power required varies approximately with the third potential of the speed). As the power absorbed by the propeller is very low at low speeds, there would be too great acceleration of the propeller at starting and, under certain circumstances, it would tend to rotate free in the water (formation of cavitation behind the propeller) without imparting acceleration to the water mass and exerting a push on the vessel. Too rapid manœuvring produces severe vibration in the vessel. Further, electrically, conditions would be inadmissible as, at low speeds, there would be very heavy currents, on account of the voltage being proportional to the speed, and these currents surges would be bad for the commutators. In standard vessels operating independently, the current-limiting regulator used according to system 3 and which causes an increased current to flow when the speed falls, is, therefore, the most suitable solution.

On the other hand, a regulation to constant load for a certain range of loads is important on tugs, ice breakers, that is to say on vessels with variable travelling resistance to overcome. Fig. 21, for instance, reproduces the curves established for a Diesel-electric driven tug (shaft output, pull on the tow hook, travelling speed) in function of the number of revolutions of the propeller when the vessel is travelling free, or towing various loads or else when secured (dock test). An examination of the load curves (Fig. 21) shows, immediately, the advantages of Diesel-electric drive as compared to direct Diesel drive. When, in the case of direct propeller drive, the Diesel engine is so dimensioned that it gives its rated output at point A_1 when the vessel is travelling free, this output is reduced, when the vessel is towing, owing to the fall in the propeller speed and, for a heavy towing load, it corresponds to point C_4. If, on the other hand, the Diesel engine is so dimensioned that it is giving full load at point A_4 it must be designed to too big an output in order to correspond to point C_1. With electric transmission on the contrary, a Diesel engine suffices—for all towing conditions—which is only dimensioned according to point A_1, this because it is independent of the propeller speed and runs at constant speed itself, i. e. can work at constant output. Therefore, on vessels having to meet variable travelling resistances, but only on these, automatic regulation to constant load within a speed range defined by the variable travelling resistances to be negotiated (for example according to A_1, A_5 or B_1, B_5) is not only suitable but very desirable.

This problem of automatic load regulation is very easy to solve with the help of a Brown Boveri quick-acting regulator connected up as a current regulator and operating on the field of the propeller motor[1]. The fundamental diagram of connections (patented in different countries) is shown in Fig. 14. The plant usually operates in Ward-Leonard connection. When the vessel is running without tow load (load curve L) and under full load (operating point A) the potentiometer P is in its end position. If the travelling resistance encountered increases, for example ice or a load in tow (Load curve L′) and allowing that the potentiometer P is left in the same position, it is obvious that the same Ward-Leonard voltage and, therefore, the same r. p. m. as in point A is maintained. This gives rise

[1] Brown Boveri also build automatic control equipments, especially for Diesel-electric rail vehicles, in which the output of the Diesel engine at different speed steps is held automatically constant at values which are adjusted for in the driver's cab (constant torque at different speeds of the Diesel engine). Although this control is the most perfect existing, for the object in question, it must be said that it is not, in general, necessary for Diesel-electric D. C. ship propulsion, as in these plants, the Diesel-generator sets usually run at constant speed while traction Diesels run at a whole series of service speeds, which makes more onorous demands on the control equipment. In Diesel-electric ship propulsion with A. C., however (see The Brown Boveri Review, year 1932, page 148), control to constant Diesel torque has a great field of application, as, in this case, the speed of the Diesel engines is varied.



to the danger of the plant being considerably overloaded, both as regards current and output (point C), for which neither Diesel engines nor electric machines are dimensioned. The quick-acting regulator PR, which is influenced by the current in the Ward-Leonard circuit and tends to hold the latter constant, now prevents an increase of the main current, automatically, by strengthening the field of the motor. The r. p. m. of the propeller shaft drops and the operating point is displaced from A to B. As the Ward-Leonard voltage is the same in B as in A (the potentiometer not having been moved) and as the main current is kept constant by the regulator, the plant works on point B with the same output. From point B, the r. p. m. can be regulated down, in the usual way by moving the potentiometer, that is to say by altering the Leonard voltage along line B 0. The load to be held constant can always be adjusted within certain limits with the help of regulator PR. This shows that the quick-acting regulator, termed a *tow regulator* in this case, allows of travelling with constant load automatically when the resistance encountered varies, the captain making use of the potentiometer in the usual way and quite regardless of travelling conditions. It is impossible for excessive overloading of the Diesel engines or electric plant to take place, this even if the vessel or propeller is blocked.

These examples will have shown that the control system developed by Brown Boveri for Diesel-electric ship propulsion is the most perfect that can be suggested with regard to service reliability, simplicity and economy.

Fig. 21. — Characteristic curves (S. H. P., pull on towing hook, travelling speed) of a tug boat travelling free and with various tug loads, in function of the speed (r. p. m.) of the propeller.

n. Speed (r. p. m.) of propeller.
SHP. H. P. on propeller shaft.
kg. Pull on towing hook, in kg.
kn. Speed of vessel, in knots.
1. Travelling free without tug load.
2. With light tug load.
3. With average tug load.
4. With heavy tug load.
5. Vessel fastened to dock (dock test).
a. Limit curve for constant rated load of Diesel engines (375 B. H. P.).
b. Limit curve for constant overload of Diesel engines (425 B. H. P.).

The curves are records of tests which the Atlantic Refining Co. Philadelphia, carried out on the Diesel-electric driven tugs "van Dyck 1" and "van Dyck 2". The values published are marked with an "x".

Hundreds of Brown Boveri quick-acting regulators are used on ships, to-day. They have given equal satisfaction under the rough conditions of trawler service, first-class passenger ship service, on submarine and big warships; on the latter, in particular the regulator is unaffected by the sharp shocks caused by gun fire.

(MS 912) *E. Klingelfuss. (Mo.)*

ELECTRIC DRIVES IN THE RUBBER INDUSTRY.

Decimal index 621. 34 : 678.

THE machinery used in the rubber industry can be divided into two classes according to the kind of work performed and the method of operation. One class of machines which serves to prepare the rubber—washing machines, mills, mixers, kneading machines—is characterized by large power input, constant speed and very irregular loading with sudden load peaks. The other class, for carrying out the finishing processes—calenders, tube machines, vulcanizing presses—consumes less power and runs under steadier loads

but with, often, a very wide range of speed variation. The following paragraphs give a summary description of some recent electrical drives delivered for machinery of this kind.

Fig. 1 shows an example of *reduction gearing* for the drive of machines used for preparing rubber. For specially heavy service, Brown Boveri build helical gearing and incorporate sprung devices to deaden sudden load shocks and save the teeth. The method of lubrication by the gear wheels dipping in oil makes accessory lubricating apparatus such as pumps, manometers, etc. unnecessary, so that attendance on the gearing is limited to examining the state of the oil and its level, from time to time.

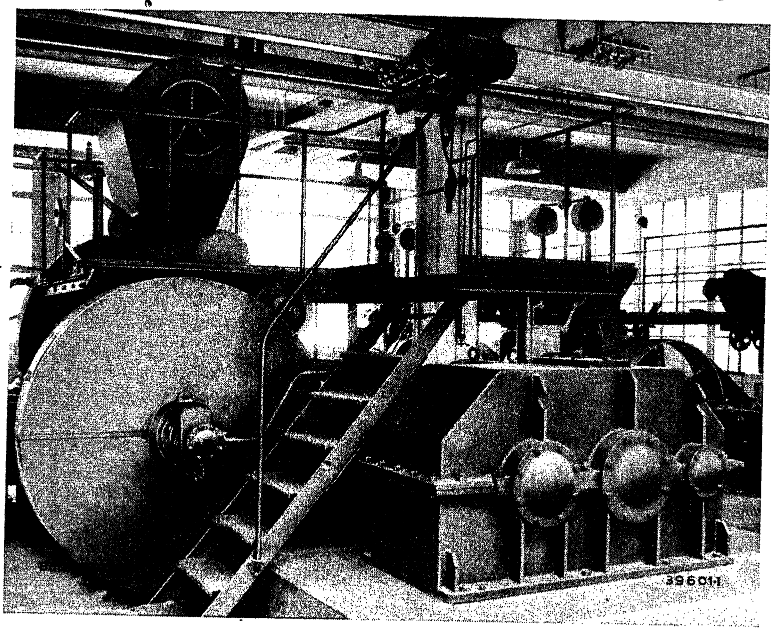


Fig. 1. — Drive of a rubber kneader through a two-step reduction gear, 135 kW (gear ratio 1 to 15).

The *shunt commutator motor* has been introduced very successfully for variable speed drives in the rubber industry. Fig. 2 shows one of these motors *driving a rubber calender*. The speed can be varied in a range of 1 to 8 by simply displacing the brushes and this with, practically, no losses and perfectly smoothly (without steps). Service is considerably simplified, by using remote-control devices. A casing containing three push-buttons: "Close-faster", "Slower", and "Stop", is mounted beside the calender. As soon as the main circuit breaker is closed and the push-button "Close-faster" has been depressed, the main contactor closes and the motor starts up under moderate current consumption and its speed increases until it reaches that corresponding to the lowest limit of its speed range. By continual pressure on the same push-button, the brushes can then be displaced as desired from this position, through the agency of the built-on servo-motor. When the "Stop" push-button is depressed, the motor is cut out and the brush rocker brought back, simultaneously, to the starting position, so that when the motor is switched in again it starts with its brushes in the proper position. It is, thus, impossible to make mistakes in operation.

Special measures are taken to avert danger. In order to be able to stop the calender quickly if, for example, a workman's hand has got drawn into the rollers, the driving motors work through a slip coupling the calender-side half of which can be rapidly blocked in an emergency, while the motor is brought to a stop by the counter torque of the coupling but without excessive mechanical shock. This measure is necessary on account of the big flywheel effect of the motor which makes it difficult to stop it in a short time by electrical means.

The braking process takes place in the following manner:— when a wire stretched in front of the calender is pulled, the catch of a switch is tripped and this switch energizes the brake magnet. The latter now frees the mechanical brake which acts and brakes down the calender quickly, while simultaneously opening the main circuit breaker,

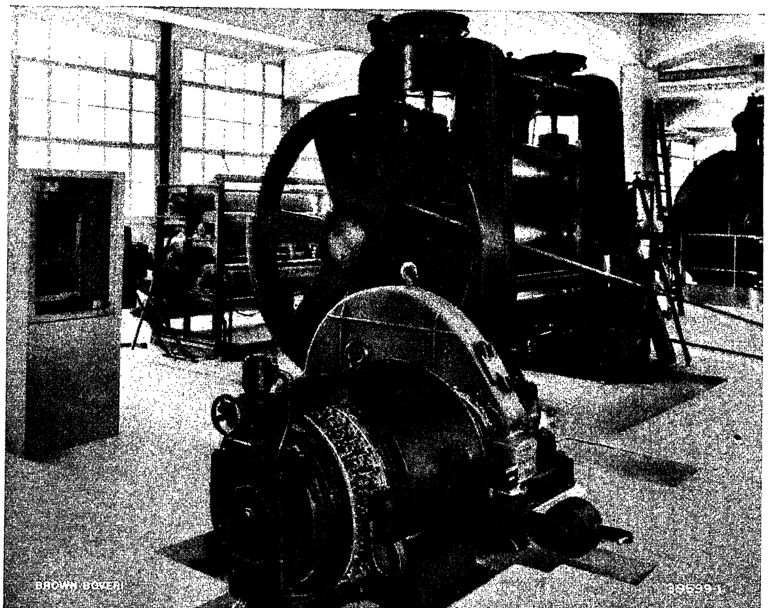


Fig. 2. — Drive of a rubber calender by a 60-kW three-phase *shunt* commutator motor, with speed regulation in a range of 970 to 127 r. p. m.

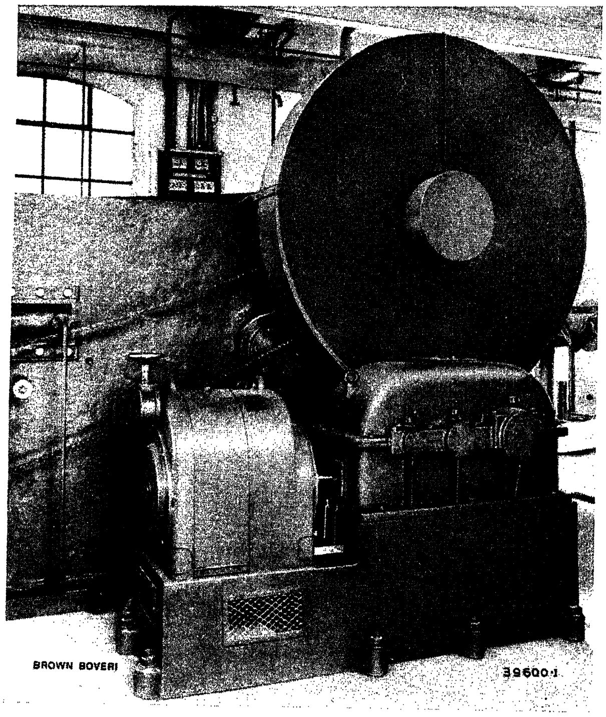


Fig. 3. — Drive of a vulcanizing press by a 7·5 kW three-phase *shunt* commutator motor, with speed regulation in a range of 1500 to 300 r. p. m.

by the opening of an auxiliary switch. The opening of the main circuit breaker causes the current to the brake-lifting magnet to be cut out, immediately after it has acted. Current, thus, flows through the brake magnet coil for a short time only and the brake magnet need, therefore, be of small dimensions, only. The braking effect can be enhanced, if desired, by a device which brings the brushes of the motor back rapidly which causes the motor to work as a generator and produces a very high braking torque. In the plant under consideration here this latter measure was not considered necessary.

The *shunt* commutator motor is also very suitable to drive *vulcanizing presses* for making rubber flooring slabs (Fig. 3). The only duty of the drive, in this case, is to regulate the draw speed of the material. It is very clear that this function cannot be performed more easily or better than by a *shunt* commutator motor as by one single movement the brushes can be displaced and the speed regulated and, at the same time, the stator switch can be closed or opened.

For certain special duties, however, it is impossible to dispense with the D. C. motor. In *tire-making machines* different working conditions have got to be adjusted and all functions have got to be initiated by simple pressure on a foot-operated switch. For this, drives in Ward-Leonard connection are used, which are characterized by their extraordinarily simple control.

The machines are driven by a motor of low output the speed range of which is about 1 to 3. This motor runs alternately in both senses of rotation, sometimes at its lowest speed and at other times at any other speed dictated by the regulator; it must sometimes run for a short time only (inching), or else run continuously till the end of the process and then brake down to a stop after each cutting out.

The control (Fig. 4) is so designed that one single contactor suffices for the switching operation. The sense of rotation and speed desired are set by a small auxiliary switch and a field rheostat; for operating the machine, there are two foot-operated switches placed at the two operator posts. One of these switches closes the control contact but only for as long as pressure is exerted on the switch and the motor then runs for the same length of time and is immediately braked to a stop electrically when the foot switch is allowed to open. The inching process can thus be carried out with great exactitude. The other foot-operated switch is, further, provided with a catch device, to allow the motor to run till the switch is tripped by a light blow.

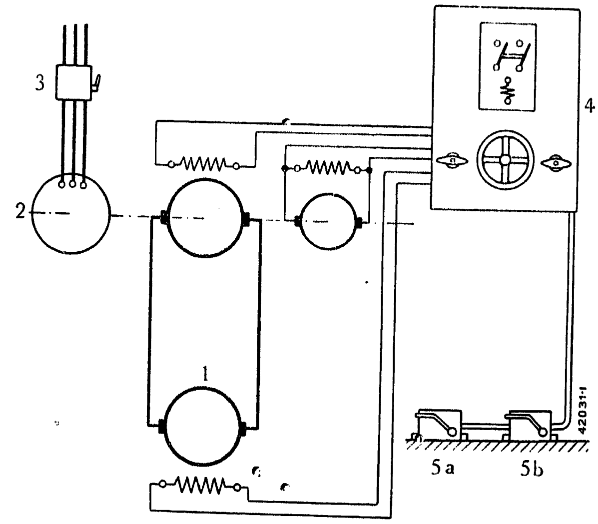


Fig. 4. — Fundamental diagram of connections for the drive of a tire-making machine.

1. Driving motor.
2. Regulating set.
3. Switchbox for motor.
4. Switchgear panel.
5a, b. Foot-operated switches.

This control system which has been developed from the experience gained with other machine-tool drives, has given such an excellent account of itself that, in one case, after trial operations in a plant, five other similar equipments were ordered. Thanks to the adaptability of this control, the most varied requirements can be satisfactorily fulfilled and the drive can be used in all plants where a motor has to be started up, regulated, reversed and braked in as simple a manner as possible.

(MS 920)

S. Hopferwieser. (Mo.)

NOTES.

A high-voltage mutator for wireless transmitting stations.

Decimal index 621. 314. 65 : 621. 396. 71.

BROWN BOVERI was the first firm to introduce the mutator as a source of power for wireless transmission. The practical results attained, in the first plants thus equipped, were so encouraging, in every respect, that the development of the high-voltage mutator was proceeded with and, to-day, the firm is in a position to deliver single mutator units which meet every requirement of commercial wireless-transmission service, as regards voltage and output. By far the greatest number of new high-power transmission stations are equipped with high-voltage mutators and, with the exception of a few plants, all these units have been built by Brown Boveri. Up-to-date, the firm has 60 wireless-transmission mutators operating or on order, delivering an aggregate power of 26,100 kW, which corresponds to an average output per unit of about 435 kW, the D. C. voltage being between 12,000 and 22,000 V.

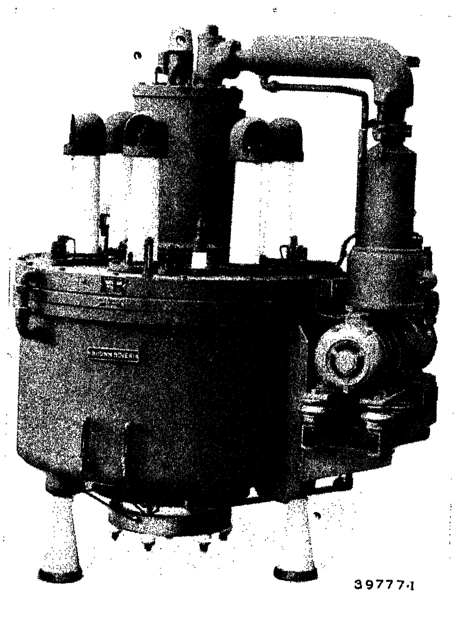


Fig. 1. — High-voltage mutator of 1000 kW output at 20,000 V, 50 A.

The first wireless-transmission plants worked to D. C. voltages of about 12,000 V but, in recent years, this voltage has been doubled. As regards power, as well, there has been a notable increase; thus, wireless transmission units of up to 1000 kW have been built. Fig. 1 shows one of the latest Brown Boveri mutators for a powerful wireless-transmission station which is equipped with three mutator sets each of 1000 kW at 20,000 V.

The continuous progress being made in the technique of wireless transmission justifies the view that the big wireless transmitting posts of the near future will contain units of still greater output using higher voltages and that it will not be long before the output of the mutator units for this service will reach several thousand kilowatts and the voltages attain 40,000 V. The research work already carried out in Brown Boveri test plants and the practical results from existing stations which are available all go to prove that the firm will be in a position to produce mutators meeting the said requirements in every respect.

(MS 930) *C. Brynhildsen. (Mo.)*

Noiseless squirrel-cage type motors for driving lifts.

Decimal index 621. 34 : 621. 876.

THE noiseless motor with squirrel-cage rotor, in outputs up to about 10 kW, is being used more and more frequently for the drive of lifts. The reason for this is to be sought in its simple design and stout construction as also in the simplicity of its starting gear. No starting resistances are required and only two contactors are wanted to switch in the squirrel-cage motor and to reverse its sense of rotation.

A lift motor must not be simply noiseless, it must develop a powerful starting torque under a low starting current. These conditions are fulfilled by the motors built by Brown Boveri with their special squirrel-cage rotors, termed "high-torque motors". They develop a starting torque which is double the running torque and take a starting current which is only about three times the running current.

As a rule, lifts do not run all the time, but are called on to give intermittent service and to work for short running periods. The motors which drive lifts are, therefore, designed for short periods of service or long pauses between the service periods. Service conditions for intermittent service are characterized by the relative switched-in time of the motor, the said relative switched-in time being designated by the ratio of switched-in or load time to the time corresponding to a whole operating cycle. The latter is the sum of the switched-in time and of the switched-out time. Standard relative switched-in times, for lifts, are 25 % and 40 %.

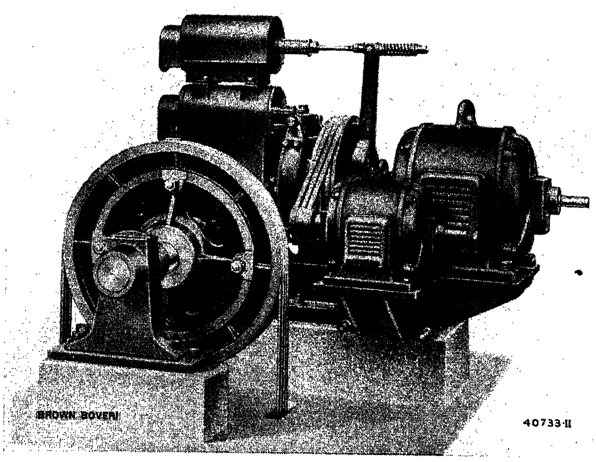


Fig. 1. — Brown Boveri three-phase motor with squirrel-cage rotor for practically noiseless running (drive of a lift winding-engine).

The switched-in time is, however, not the only important factor in chosing a squirrel-cage motor for lift drive, the number of starting operations per hour is also of importance. For lifts to carry goods and for passenger lifts, called on to make up to 60 trips per hour, motors for 25 or 40 % relative switched-in time can be chosen, according to the length of the switched-in time. For more than 60 trips and up to about 120 trips per hour, a motor for 40 % relative switched-in time is generally used; in these cases the lifts in question are usually in office buildings, warehouses, or lofty buildings.

Fig. 1 shows a hoisting winch with precision adjustment delivered by the Wagons- & Aufzügefabrik Schlieren (Switzerland) and driven by Brown Boveri motors with special squirrel-cage rotor. The big motor moves the lift between the storeys at standard full speed while the small motor moves it just before it stops and at a lower speed, namely that of the precision adjustment. Lifts, equipped with precision adjustment stop at the different storeys without any preliminary inching movement which allows of faster and more comfortable emptying and filling of the lift when it is a passenger one. Goods lifts must, however, often be equipped with precision adjustment, as well, in order to make them stop exactly and sharply, a necessary condition when trucks are carried up and down and have to be run in and out of the cage.

Fig. 1 shows the precision adjustment of the Wagons- & Aufzügefabrik Schlieren (Switzerland) with a small motor mounted separately which drives the hoisting winch at low speed, by belt. As soon as the lift approaches the storey where it must stop, the main-motor is cut out while the coupling magnet above the winch is energized. This causes the pulley with the grooves of the wedge friction belt to be pressed onto a counter pulley which is designed as a friction clutch and rigidly connected to the shaft of the motor. The lift is, thus, mechanically braked to begin with; the precision-adjustment motor is now put under voltage and moves the cabin of the lift at a reduced speed until it reaches the stop position, where the stop brake brakes it to a standstill.

There are other solutions for the precision adjustment of a lift, one being, for example, to use a motor with interchangeable number of poles, in which the lower speed is used as precision-adjustment speed.

In recent years, Brown Boveri has built a great number of lift motors of their special squirrel-cage rotor type; these have given entire satisfaction in service.

(MC 923) *E. Altschul. (Mo.)*

Individual electric drives in bast-fibre spinning mills.

Decimal index 621. 34 : 677.052.3.

INDIVIDUAL electric drive did not find as rapid or as widespread favour in spinning mills making yarn of flax, hemp and jute for all kinds of fabrics, string and rope, as it did in the other branches of the textile industry. In some leading producer countries line-transmission drive with a central steam power station or with group drive by electric motors still holds its own. Nevertheless, it can be confidently stated that it will only be a question of time before individual drive has ousted line-transmission drive, entirely. It is a illuminating fact, amply proved by past experience, that the introduction of electric drives into bast-fibre spinning mills means a considerable raising of the quality of the product and increase in the quantity produced, which, in fact, conforms to the experience gained in cotton and woolen mills. This applies to individual drive, in particular, and is explained by the adaptability of the latter, by the constant working speeds it allows which means a higher working speed than that attainable with the fluctuating speeds of line-transmission drive and by the possibility of speed regulation by simple means. A further advantage is the more efficient use made of the space and of the power available. It is true, however, that the organization and local working conditions play a part in the choice between group drive and individual drive and this applies also to the kind of raw material used and quality of the finished product. The preponderant factor in the end, however, is maximum productivity at lowest cost, objects which can only be attained by means of economic and far-reaching division of the power available, by means of direct drive of the working shafts at their most advantageous speeds, and this means using individual drives.

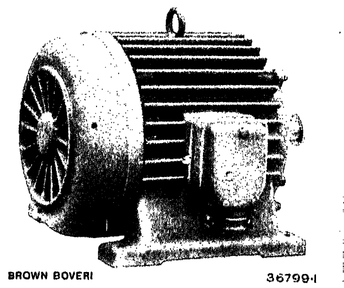


Fig. 1. — Totally-enclosed squirrel-cage A. C. motor, Type MQUe with external air-draught cooling.

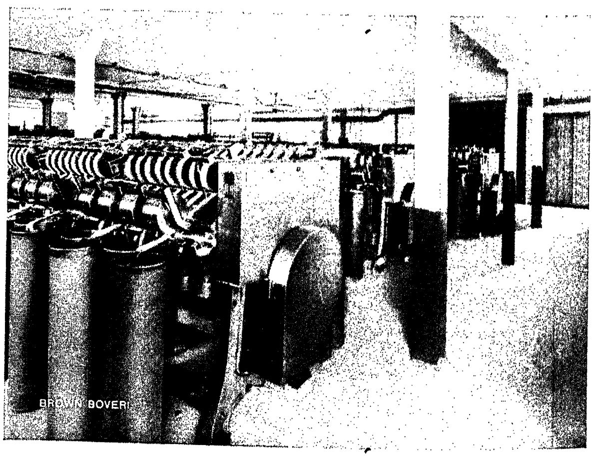


Fig. 2. — Gear drive of tow-drawing frames by built-in, totally-enclosed squirrel-cage motors.

In chosing the motors, it must be remembered that they are exposed to a considerable amount of dust as well as to vapours and damp in the case of wet-spinning machines. Under these conditions, motors of open design

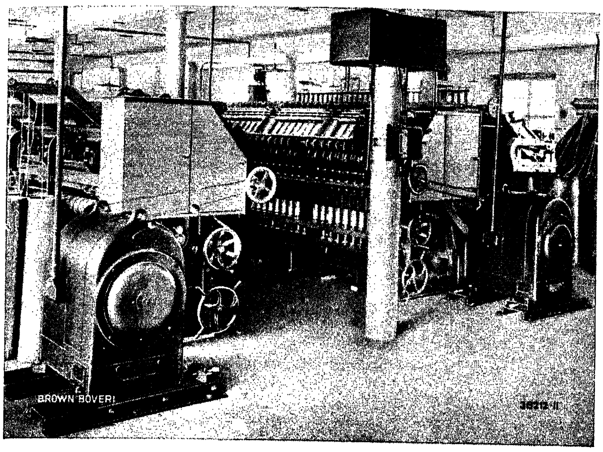


Fig. 3. — Variable-speed drive of Gill-spinning frames by three-phase, *shunt* commutator motors, Type PND, remote-controlled by contactors and push-buttons.

require a great deal of supervision and their windings are in danger of deterioration, so that totally-enclosed motors should be given preference. Externally-cooled motors can, practically, be left to run alone, apart from an occasional bearing inspection (Fig. 1). The very slightly higher cost of purchase as compared to open-type motors is soon compensated for by the saving in attendance. Pipe-ventilated motors, for connecting to ventilation ducts are used for commutator motors driving spinning frames (Fig. 3).

For most of the preliminary preparation machines, simple, stout squirrel-cage motors (multi-slot or deep-slot) can be used, to be straight connected to the supply system. Attendance at starting and stopping is confined to closing and opening the switch of the switchbox. Apart from the said switch with thermal relays, a special control switch, governed from the control rod of the machine being driven, can be used in cases where switching operations are frequent. Direct drive through reduction gearing or V belts should be used as often as possible, as it allows of placing the machines close together, axially and of saving space. The driving motors of the tow-drawing frames (Fig. 2) are lodged in the shield of the frames proper. For card drive, if group drive is not retained, belts with movable jockey pulleys are generally used, on account of the considerable work of acceleration to be carried out at starting. Hemp and jute softening mills are generally driven by slip-ring motors on account of their difficult starting conditions and jerky-running conditions. Sufficiently smooth starting of roving frames is attained, even with reduction gearing, by proper choice of the motor output with regard to the power requirements.

Special interest attaches to the individual drive of the Gill-spinning frames and of the flyer-spinning frames, because this type of drive allows of improving manufacture and increasing production to an even greater extent than with the machines of the first manufacturing stage. Gill-spinning frames and flyer spinning frames must start smoothly and speed regulation is very desirable and advantageous so as to allow of beginning spinning with a low speed and to permit of suiting the spinning speed to the various kinds of raw material used as well as to the yarn number and sort worked with. Frequently, speed regulation during the spinning process is advantageous, whether it is carried out by hand or automatically, by a spinning regulator. These requirements are admirably fulfilled by the three-phase *shunt* commutator motor the speed of which can be regulated perfectly smoothly over a wide range, by displacing the brushes, which is done by a single movement. These motors are built to be connected up to the voltages usually met with in spinning mills (Fig. 3). The most advantageous spinning speed can, therefore, be adjusted to at all moments. These motors are of the enclosed design and usually built for pipe ventilation and to be connected to air ducts. For bast-fibre spinning mills, they are provided with built-on reduction gears and are directly coupled to the tin-roller shaft. V-belt drive is also suitable here. The Gill-spinning frames for flax (Fig. 3) are mounted in a plant equipped with individual drive throughout. Variable speed drive proved extremely important for the profitable utilization of these modern productive machines with automatic doffing motion. Apart from the easy setting of any desired flyer speed, between 2400 and 5000 r. p. m., by means of the control handwheel, push-button control is highly appreciated for inching, for beginning the bobbin and for stopping. "Inching" takes place especially quickly and reliably. A brief pressure suffices to impart through the motor a few rotations to the flyers and to place the first turns on the empty bobbins. The delatory process which must otherwise be used for this by means of a jockey pulley is eliminated. An emergency switch allows of stopping the drive immediately and from any part of the machine.

It is obvious that spinning machinery equipped with variable-speed drives of this kind must be far more efficient than with line-shaft drive or squirrel-cage motor drive in which changes in speed must be carried out in steps by changing the pulleys, or else is not possible at all. Despite this, cheap motors with squirrel-cage rotors are often put up with, either to cheapen the plant or because the conditions of production make speed variation seem less urgently necessary. Variable-speed drive can, however, be useful even in plants which always produce the same kind of yarn, because it encourages tests with other and, chiefly, with higher spinning speeds and thus opens the way to increased production of the machines and to a more competitive value of the plant. The encouraging results of practical service with variable-speed three-phase *shunt* commutator motors, show that their

higher cost is absolutely justified by results. This type of drive is meeting with increasing interest and will certainly find more frequent use in bast-fibre spinning mills than it has, so far.

(MS 922) *H. Wildhaber. (Mo.)*

The 1000-kW three-phase turbo-set, for 120 and 160 cycles for the Chodakow artificial silk mill (Poland).

Decimal index 621. 313. 322. 1. 025. 6 (438).

VISCOSE artificial silk is made of sulphite cellulose which is first treated with a caustic soda solution and with carbonic bisulphide. After further preparation, a sluggish liquid is produced, namely Viscose, which is pressed into a fixation bath by a small pump, through spinning nozzles of about 1/10 mm diameter. The parallel threads, issuing from the spinning nozzles and passing to the fixation bath, are immediately strengthened and can be doubled and wound up on spinning centrifugal pots. The latter run at 7200 to 9600 r. p. m. and are direct-driven by two-pole vertical-shaft motors, with squirrel-cage rotors. It would be unsuitable to insert reduction gearing as, owing to the high speeds, it would be difficult to attain quiet running on account of the critical speeds encountered. It is, therefore, necessary to have available three-phase current at 120—160 cycles.

In various artificial-silk mills, as much as 1000—1500 kW are needed, to-day, under the form of three-phase current at this increased frequency. The Chodakow artificial silk mill, in Poland, recently placed an order with Brown Boveri for a turbo-set to generate three-phase current at 120—160 cycles. It is composed of a back-pressure turbine of the combined type with a maximum continuous output of 1000 kW at 4200 r. p. m. It is direct-coupled to a three-phase generator which delivers 1000 kW at 4200 r. p. m., p. f. 0·7, voltage 520 V and frequency 140 cycles. The output and the voltage of the generator vary proportionately with the frequency. The exciter of standard type is mounted overhung. The automatic quick-acting regulator is so set by means of an adjusting rheostat that it is possible to maintain constant voltage when passing from one frequency to another.

By using high-grade dynamo sheeting, the iron losses were kept low even when operating at the higher frequency. Special attention was devoted to rendering the stator winding short-circuit proof.

A frequency of 120—160 cycles per second corresponds to a speed of 3600—4800 r. p. m. when the generator is direct-coupled to the turbine. It was, thus, possible to attain advantageous steam-consumption figures without it being necessary to use a geared turbine. The steam consumption figures at 4800 r. p. m. are still 6% better then at 3600 r. p. m.

Smooth changing of the speed of the turbine within the limits of 3600—4800 r. p. m. is easily carried out by means of the standard speed-adjusting device. The frequency need not be altered during service as the speed of the spinning centrifugals for twisting and winding up the thread in the revolving spinning pots is constant. Another spinning-centrifugal speed corresponding to a different thread speed and twist, when changing over to producing another garn number, makes a change in the speed of the spinning centrifugals necessary. It is an advantage to be able to alter the speed of the spinning centrifugals between 7200 and 9600 r. p. m. by altering the speed of the turbine, only. When motor generators are used for converting three-phase, 50 cycles into three-phase of the higher frequency, this smooth speed regulation is not possible, unless three-phase shunt commutator motors be used.

The back-pressure turbine for the Chodakow artificial silk works is built for a live-steam pressure of 20 at abs, a temperature of 400° C and a back pressure of 3 kg/cm³ abs. The exhaust steam from the turbine is used for preheating water, drying and warming processes in the artificial-silk works. It is not necessary to regulate the pressure of the process steam. The exact balance between power requirements and process-steam requirements is attained thanks to there being two other three-phase turbo-sets, of the condensing type, running in the Chodakow plant, which generate power at 50 cycles. The two latter sets were also delivered by Brown Boveri.

A similar set was ordered recently for the Tsuruga artificial silk mill (Japan). This set is for an output of 1500 kW at 4050—4650 r. p. m. and is to be used to generate three-phase current at 135—155 cycles. This turbine is of the extraction type, a design which has the distinct economic advantage for this plant in particular of generating power simultaneously and proportionately to the volume of process steam required.

(MS 933) *G. Leidig. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2) : 621. 313, 322 (494).

IN Switzerland, classic land of electric power supply, there is a whole series of electric power generators, which are running perfectly, and are real veterans among Brown Boveri products.

As an example, the firm of Spörry & Co. in Flums have three three-phase generators now running in their Pravizi plant which were delivered in 1900 and 1901. These units deliver 985 kVA each and are wound for 5000 V, 50 cycles, p. f. = 0·8. They have built-on exciters and run at 500 r. p. m. Their factory numbers are 6774, 6780, and 6822.

Messrs. Hermann Bühler & Co. of Winterthur has one Brown Boveri three-phase generator in their Linsenthal plant and one in their Sennhof plant. Both machines were delivered in the year 1906. The Linsenthal unit delivers 148 kVA, p. f. = 0·8, 545 V, 50 cycles at 500 r. p. m. and the Sennhof unit 250 kVA, p. f. = 0·8, 525 V, 50 cycles at 214 r. p. m. Both alternators have built-on exciters.

All these generators have run during this long period of service without requiring repairs of any importance.

(MS 935) *Prop.*

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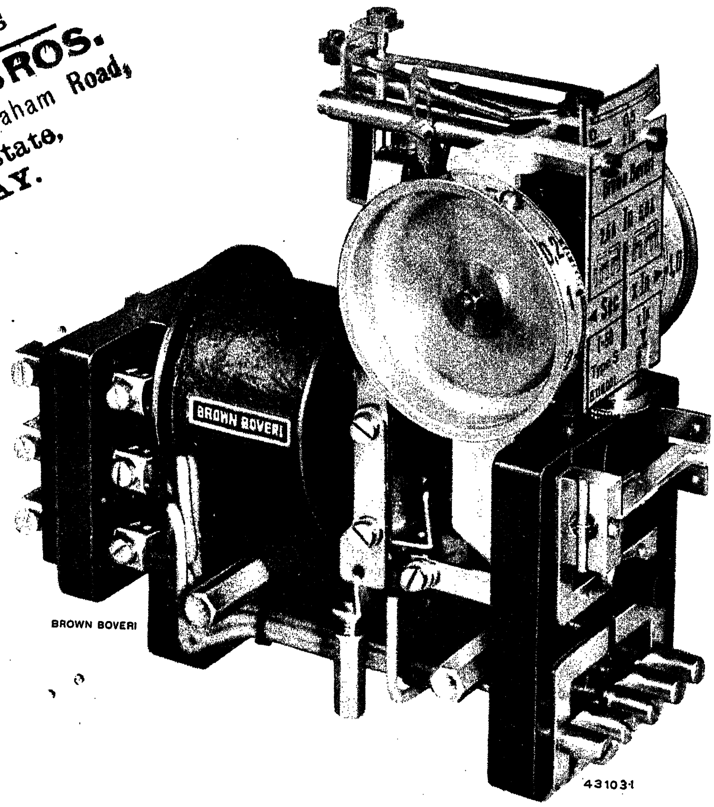

THE CURRENT-INDICATING SECONDARY RELAY TYPE S.

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THE BROWN BOVERI REVIEW

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THE CURRENT-INDICATING SECONDARY RELAY TYPE S.

Decimal index 621. 316. 925. 43.

THE Brown Boveri secondary relay, Type H 2, in use up till now, was formed, for the greater part of the elements used in the earlier series relay Type H 4, the latest constructive modifications of which were, recently, commented on[1]. It was, obviously, advantageous, from a manufacturing point of view, to be able to use the same parts for both types of relay. The magnetic system of a primary relay, however, is designed, primarily, with a view to the considerable mechanical energy required for direct tripping of the breaker and it is, therefore, unsuitable for a secondary relay which has only one contact to actuate and when the reduction of power consumption to a minimum is of great importance. It was, therefore, expedient to replace the existing secondary-relay design by a new one incorporating the properties enumerated in the following paragraphs.

I. GENERAL NOTES.

The field of utility of the secondary relay is, in many respects, identical to that of the primary or series relay. Secondary relays are, generally, given preference in switchgear plants where supervision is centralized, in outdoor stations with an enclosed apparatus room, in high-voltage plants and, always, in plants in which reverse-power relays are used besides those acting on time lag and on current strength.

Secondary relays are built either as inverse time-limit relays or definite time-limit relays. The dependence of the time lag on the strength of the current is a natural characteristic of relays having a Ferraris disc, which is the oldest of all relay designs, and this property used to be all the more appreciated, as it introduced into intermeshed systems, for example, a certain selective element which made itself felt when short circuits had to be cleared. It should be said here, however, that the inverse time-limit relay is being more and more ousted from this field by the more recent distance relay. Considered from the point of view of protection against overloads, inverse time-limit relays were, also, only superior in a very few instances to definite time-limit relays; this was especially so as the time lags are far from allowing the range requisite to proper overload protection, based on the temperature rise of whatever apparatus is being protected. The uncertainty as regards the setting of the tripping time in networks having a varying power supply, as well as the impossibility of making these relays work together with relays having time lags which varied with the arc resistance were all factors influencing against the inverse-time character, and in favour of definite time limit relays. The fact that inverse time-limit relays are by far the most numerous on the market is to be explained less by a demand for relays of this kind as by the non-existence of a definite time-limit relay combining the welcome simplicity of the inverse time-limit relay to its low power consumption — which latter point is really the crux of the problem.

Especially in the case of bushing transformers, which can only furnish a small amount of energy, when the current ratings are small, the question of the power consumption of a relay is often the decisive factor in defining its field of application.

A solution of the problem of using definite time-limit relay settings along with low power consumption is found by using separate elements for the pick-up current and for the time lag proper, the design being such that the pick-up current organ instantaneously establishes a contact when the current setting is exceeded and thus switches in the separately-arranged time element which, in its turn, acts on the tripping contact after the desired time lag had expired. This solution can be realized with a very low VA consumption. It calls, however, for very sensitive auxiliary contacts, increases the number of apparatus entailed and always requires an auxiliary source of power, so that it can, really, only be considered as an expedient to be used in very complicated cases.

[1] The Brown Boveri Review, year 1935, No. 6, page 119.

In cases like this, Brown Boveri use over-current relay Type R with time-lag relay Type MKT.

The guiding principal in the design of the new secondary relay Type S was the creation of an apparatus which covered the widest possible field of application. While being of the simplest design, this relay had to incorporate the following properties:—

1. Low power consumption, widest possible range of settings, precision in the maintenance of the values set.
2. All those parts and setting organs which require supervision to be visible and accessible.
3. Readiness for service to be automatically signalled. Possibility of testing the relay where it is mounted and during service.

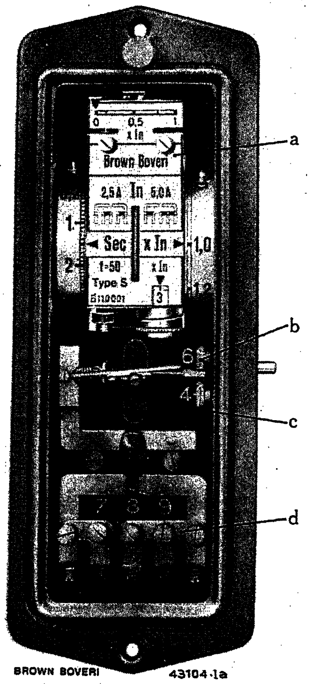

Fig. 1. — Relay Type S in casing, seen from the front.
a. Time-setting drum.
b. Relay contact.
c. Signalling device.
d. Change-over terminals.

II. DESIGN AND PROPERTIES OF THE RELAY.

Fig. 1 shows the front view of the relay in a single-pole casing. All organs which are essential to service are mounted so as to be seen clearly and to be accessible, being directly behind the hinged glass cover. The parts in question are:— the front plate a, bearing the data for all settings and indications, the relay contact b, the contact signal c and the change-over and testing terminals d.

The plate is flanked by two symmetrical setting or indicating organs, these being:—

1. The *time-setting drum* (left) allowing of making settings between 0·2 and 10 s at 50 cycles. The time scale of this drum with a scale to about 20 mm per second, allows of precise setting to 1/10 s. The figure set is held to for all currents above 2 In (In=rated current) with a margin of $\pm$ 5/100 s. For rated currents, that is to say currents the strength of which is near the lowest tripping range, a prolongation of the time lag, as compared to that set for, amounting to 2/10 s, has to be reckoned with; it is caused by the time requisite to accelerate the motor of the relay. This extra-time lag diminishes rapidly as the current increases and is completely eliminated for current settings of over 2 In.

2. The current setting drum (right) for settings between one and two times the rated current or two and four times the rated current according to how the change-over links on the terminal plate d are placed. The margin here is $\pm$ 3 % of the value set to.

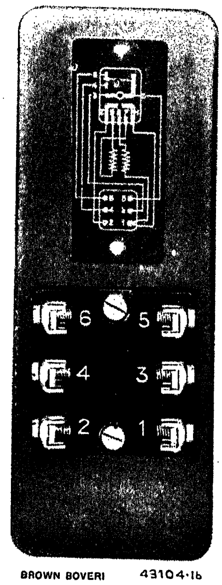

Fig. 2. — Relay Type S in casing, seen from the back.

3. The *over-current tripping device* (below), which can be set between three and five times the rated current by choice of the corresponding figure. The ∞ setting causes locking, that is to say the relay acts again to constant time lag, according to the time setting and independently of the strength of the over current. The values set to are exact with a margin of $\pm$ 5 %.

4. *Continuous indication of service current* (above) with a scale between 0 and rated current. This innovation distinguishes relay Type S. The indications on the scale are exact with a margin of about 5 %, referred to the end figures on the scale.

The scale calibration is 0—0·25—0·50—0·75—1 times the rated current.

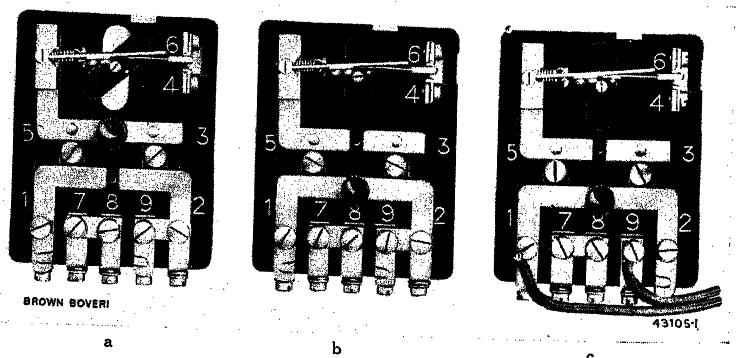

Fig. 3. — Relay Type S. Change-over terminals.
a. Ordinary service (plug in upper hole).
Signal position corresponding to contact having been made.
b. Testing conditions (plug in lower hole).
Tripping circuit broken, current transformer lead short-circuited.
c. Testing with external source of current during service.

The service current indicator allows of eliminating separately-mounted ammeters, in many cases. At the same time, this device is a constant indicator of whether the relay is in working order or not because, under ordinary service conditions, the current indications are produced by the torque generated by the Ferraris disc in its stationary condition.

The *relay contact b* can either be used as a closing contact for tripping by auxiliary current, or as an opening contact for tripping by current transformers, this according to the choice made of terminals mounted

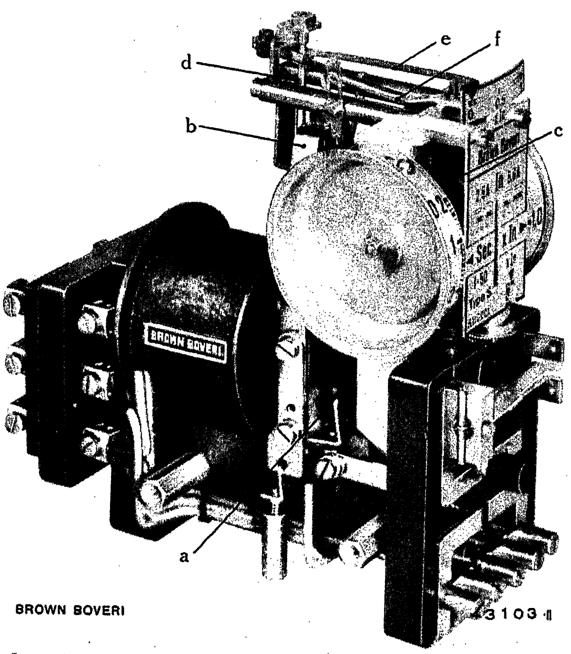

Fig. 4. — Relay Type S, cover removed.

at the back of the relay. The opening current which the contacts can handle amounts to 100 A at 220 V A.C.

The *signalling device c* to show that contact has been made causes a red mark to show when tripping has been accomplished. Incomplete contacting as happens, for example, if the short circuit is eliminated at the moment contacting is nearly accomplished is signalled by a partial apparition of the mark. This excludes wrong signalling of a switching impulse imparted, even in critical cases. Thus, a want is met which was never entirely satisfied by the use of drop discs. The resetting of the signalling device is carried out from outside, by depressing a push-button.

Station engineers, who know by experience what difficulties have, often, to be overcome in making tests on a relay built into existing switchgear, will be the first to appreciate an innovation which characterizes this relay and which consists in the *change-over* and *testing terminals d.* They allow of changing over the connections so that the relay works to another range of measurements; this being possible during service and without taking it out of position; they also allow of cutting the relay out of service or of testing it with the help of an external source of current. Fig. 3a shows the terminals in ordinary service status. After displacing the plug from the upper to the lower hole, according to Fig. 3b, the tripping circuit is interrupted and the lead to the current transformer short-circuited which puts the relay out of service. In this state, the connection links for series or parallel connection of the winding can be chosen as desired and according to the diagrammatic data shown on the plate. To test the relay, the right connecting link is opened, according to Fig. 3c, and this cuts out the relay winding on one side. By supplying current from an external source through terminals 1 and 9, the relay can be thorougly tested.

Usually, relay Type S is mounted in a narrow, flush-type single-pole casing like that used for the

Over-current definite time-limit relay Type S	At 50 cycles
Relay current:	
Range of adjustment:	
Winding coils connected in series .	1 to 2
Winding coils connected in parallel .	times the rated current chosen
Maximum error in % of current adjustment	± 3 %
Fall-back current in % of current adjustment, for lowest current adjustment	85 to 90 %
Admissible continuous current . . .	All values which can be set for
Current admissible during 1 second on thermal grounds	Normally, 100 In and up to 200 In, if necessary
Relay time lag:	
Range of adjustment	0·2 to 10 s
Maximum error for all currents . .	± 0·05 s
Prolongation of time lag	
with the lowest current adjustment	+ 0·2 s
with the highest current adjustment and all higher currents	0 sec
Limit current instantaneous tripping:	
Range of adjustment	3 to 5 In/∞
Maximum error in % of value adjusted to	± 5 %
Indication of service current:	
Measurement range referred to rated current chosen	0 to 1 × In
Indicator error referred to end-travel position of indicator	about 5 %
Relay contact:	
As desired, opening or closing contact, single-pole.	
Admissible continuous current . . .	10 A
Admissible closing current	20 A
Admissible opening current and voltage with current-transformer tripping, at 50 cycles, inductive load	100 A, 220 V
Power consumption of relay . . .	8 VA at rated current

earlier secondary relay. This casing easily finds room even in very compact switchgear and it gives very excellent protection against dust.

The external circuit terminals are on the rear of the relay, as shown in Fig. 2.

A new arrangement of relay winding as regards the Ferraris motor and a suitable design of the magnetic circuit allows of bringing the *power consumption down to only 8 VA* with the lowest tripping current which can be set for. The moving masses being small, the relay is, mechanically, to all purposes, quite short-circuit proof. Further the thermal-loading quality meets every requirement as the Table on page 229 shows; this Table gives a summary of all the essential properties of the relay.

III. METHOD OF OPERATION.

Fig. 4 shows how the relay works and other constructive details. When the tripping current set to is exceeded, the armature a exercises a pull and meshes the rotor shaft of the Ferraris motor, carried in cradle b, with the toothed disc c. The length of tooth segment which the time disc has to pass over before the relay contact is actuated, is proportional to the relay time setting adjusted to. In the rest position of cradle b, the relay motor is held stationary and this in such a manner that, as already mentioned, its stationary torque is used to actuate the service current indicator e, this with the help of axis d and of counter-spring f.

The precise setting and time exactitude of this relay allow of taking full advantage of the very short rupturing times required by modern water and air-blast circuit breakers. This relay allows, for the first time, of reducing the stepping of time settings between relays down to only 0·2 to 0·3 s, and of attaining absolutely reliable grading of the breakers placed in series on a circuit. This makes it possible to reduce to a fraction of their former values the rupturing times of short circuits.

(MS 946) *J. Stoecklin. (Mo.)*

EXTRACTION TURBO-SET OF 10,000 kW OUTPUT FOR THE STEINHAGEN & SÄNGER PAPER AND CELLULOSE WORKS, MYSZKOW (POLAND).

Decimal index 621.165.6 : 621.313.322 (438).

THE Steinhagen & Sänger Paper and Cellulose Works recently placed an order with Brown Boveri for a turbo-set. This set is to deliver 10,000 kW at generator terminals and it will be placed in the Myszkow paper mill. Like all the big paper mills, Myszkow has its own steam power station to generate the requisite amount of electric power. There are two Brown Boveri turbo-sets in this power station already, which were built in the Brown Boveri Baden works. The first delivers 2750 kW and consists of a single-cylinder turbine for an extraction of 4000 kg/h of steam, a direct-coupled three-phase generator and a complete condensing plant. It was delivered in the year 1924. The increasing business done by the said paper mill soon made it necessary to put in a second generating set with an output of 6500 kW, and this was installed in the year 1928. The turbine of this set is of the *two-cylinder type* and is designed for an extraction quantity of 10,000 kg/h. The choice of the more expensive two-cylinder turbine, here, instead of one with a single cylinder, was entirely justified, because the power demands made on the power station increased so much in a short time, that the machine is able to run during the greater part of the hours it is in service under a very satisfactory load factor. For several months, both turbo-sets have been running on week days and sundays under full load, the power station thus being without any spare-generating units, at all. It is, therefore, understandable that yet another set should be acquired.

The new set, which is built for a maximum continuous load of 10,000 kW, consists of a two-cylinder extraction turbine, with a maximum extraction quantity of 30,000 kg/h at a pressure of 3·5 kg/cm² abs. The turbine is driven by live steam at a pressure of 19·5 kg/cm² abs and a temperature of 400° C. The rotor of the high-pressure cylinder is composed of two rows of impulse blades followed by a drum of reaction blading. The steam is expanded therein down to the extraction pressure of 3·5 kg/cm² abs. The low-pressure cylinder is built for a maximum steam quantity of about 37,000 kg/h and consists of a single row of impulse blades and a large number of rows of reaction blades. When operating without extraction and using the quantity of steam mentioned, it is possible to get a terminal output of 8380 kW from the set, this with constant pressure at the extraction point and when operating purely as a condensing turbine.

The steam which flows through the low-pressure cylinder is condensed in a surface condenser which is supplied with cooling water by a closed-circuit cooling plant. The condenser is built with two separate water chambers. It is possible to shut off either half of the cooling-water system of the condenser during service and to open it up so that the tubes of the water chamber can be cleaned. There is one centrifugal

pump only, to circulate the whole volume of cooling water. The ejector pump which supplies the water-jet air ejector works in series with the cooling-water pump. There is a third pump to remove the condensate from the condenser. All three pumps are mounted on a common shaft. This pump set is driven at one end by an electric motor for three-phase current 3000 V and, at the other, by a steam turbine, the wheel of which is direct-coupled to the set. Usually, the pump set is driven by the electric motor alone and the steam turbine rotates along with it and under no load. The exhaust end of the steam turbine is connected to the condenser. The turbine only comes into action if the electric supply fails. As soon as the speed of the pump set has fallen by about 10 % r. p. m., the speed governor automatically opens the steam supply to the auxiliary turbine, which is normally closed. As the driving motor of the pump set is equipped with an automatic centrifugal starter, the said motor takes over the drive of the pump set again, as soon as the current supply is re-established. The pump set then runs at its rated speed again, and the speed governor of the auxiliary turbine closes the steam supply to it. In order that the steam turbine should not be the cause of any appreciable continuous losses when running idle with the motor-driven pump set, it is connected on its exhaust end to the condenser, a measure which reduces windage losses to a negligible value.

The three-phase generator is built for 10,000 kW, 12,500 kVA, p.f. = 0·8, 3150 V, 50 cycles and is direct-coupled to the turbine. The shaft-end of the rotor carries the overhung armature of the exciter.

Fig. 1 gives a general sectional drawing of the new two-cylinder turbine. Live steam is led to the turbine through two pipes of 250 mm bore which are connected to two nozzle-valve chests placed one on each side of the turbine. The admission of steam on to the impulse wheel is through one to four nozzle sets, according to the load on the turbine. Regulation

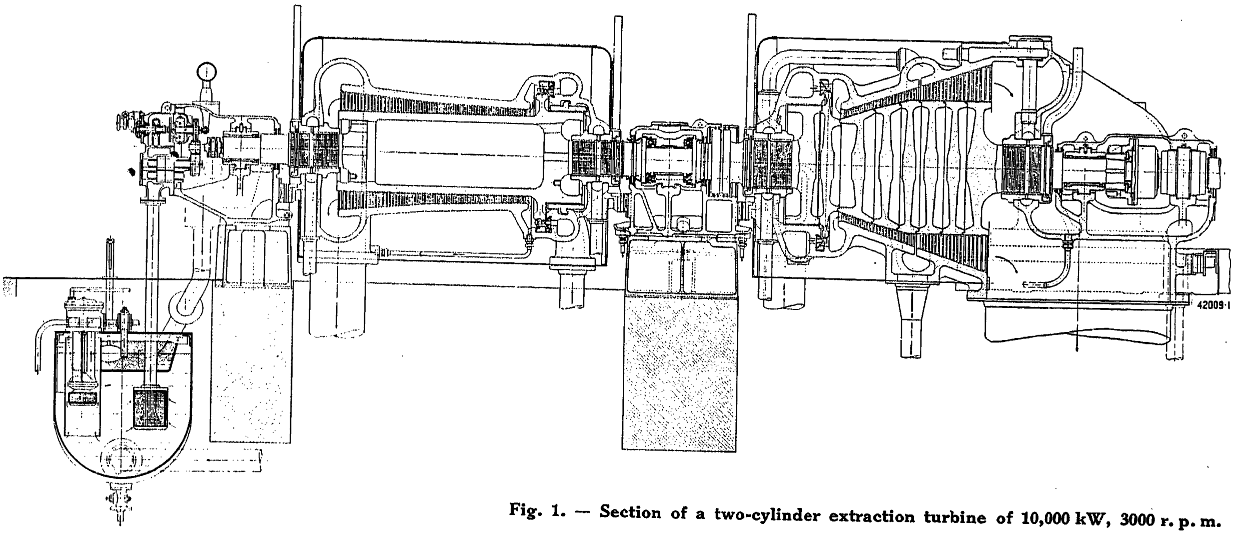

Fig. 1. — Section of a two-cylinder extraction turbine of 10,000 kW, 3000 r. p. m.

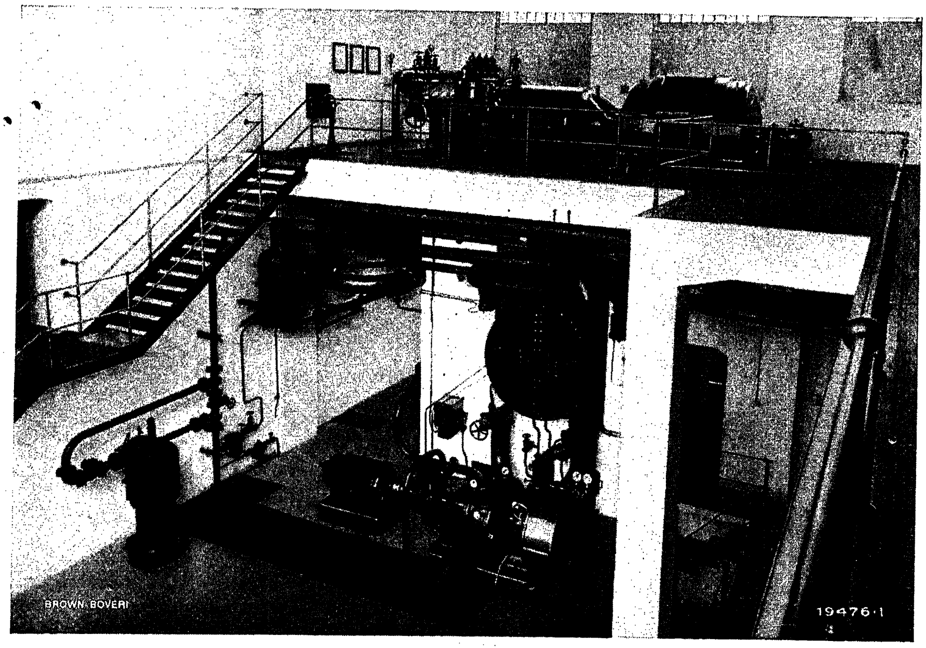

Fig. 2. — Inside of machinery hall at the time of the first development stage.

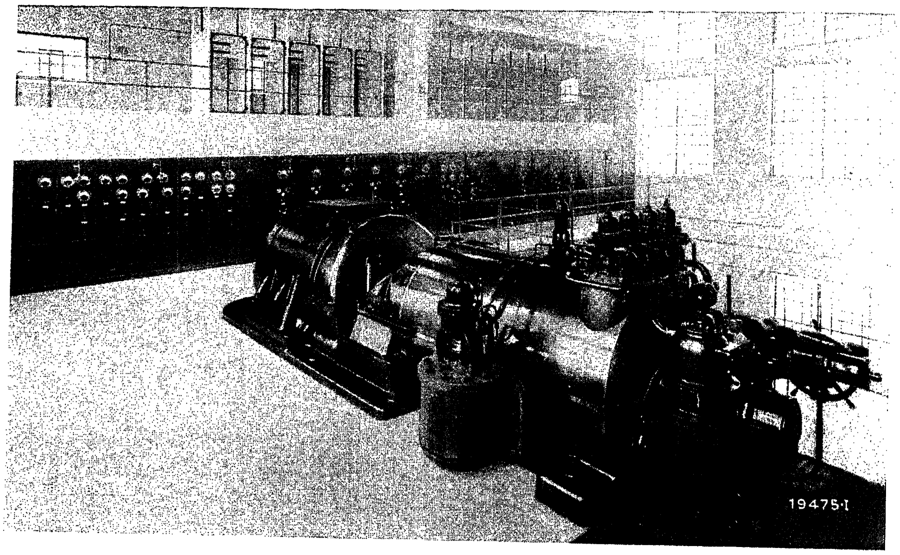

Fig. 3. — Single-cylinder extraction turbo-set of 2750 kW, 3000 r. p. m., with switch-gear plant.

designed, from the first, for extensions. Fig. 3 shows the same turbo-set with the switchgear plant.

Fig. 4 shows the second Brown Boveri turbo-set put up in the Myszkow Paper Mill, of 6500 kW output. As already mentioned, the turbine of this set is of the two-cylinder type. The available space in the machinery hall is completely taken up by the two turbo-sets now working. The building had to be enlarged to allow of putting in the new 10,000-kW set.

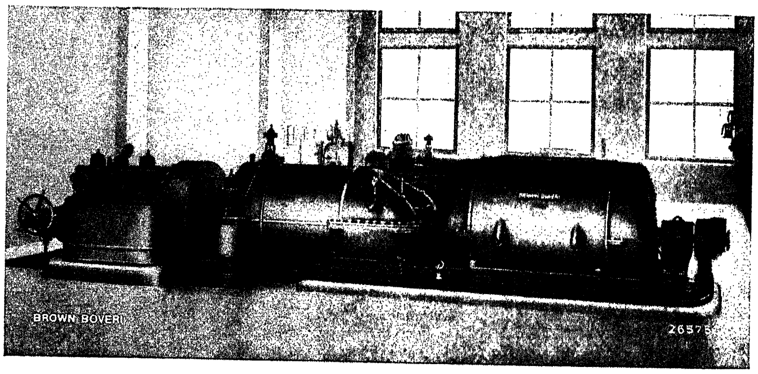

Fig. 4. — Two-cylinder extraction turbo-set of 6500 kW, 3000 r. p. m.

of steam admission is controlled by the speed governor and it depends on the load of the generator. It depends, also, on the quantity of steam extracted, being under the additional control of extraction-pressure regulating valves through the agency of the pressure regulator belonging thereto, using the well-known Brown Boveri oil-pressure governing system. The quantity of steam flowing through the low-pressure cylinder is governed by the two said extraction-pressure regulating valves which are similar to the nozzle valves on the high-pressure cylinder; this steam is admitted to the impulse wheel with its one row of blades through two nozzle sets.

Fig. 2 shows the power house of the Myszkow Paper Mill in its first development stage, with the first extraction turbo-set of 2750 kW. The illustration shows the condensing plant especially clearly. Further, the illustration shows that the machinery hall was

The steam turbine of the new set is an interesting development, *as it is among the biggest extraction turbines which have been built, so far.* This is valid both as regards its power and as regards the quantity of steam which can be extracted, which amounts to no less than 30,000 kg/h.

(MS 938) *H. Keller. (Mo.)*

AN ELECTRONIC RELAY FOR THE AUTOMATIC OPERATION OF CATHODE-RAY OSCILLOGRAPHS.

Decimal index 621. 318. 57 : 621. 317. 755.

THE continually increasing importance of transient phenomena and atmospheric disturbances due to the extension of high-tension networks has necessitated the development of a means of investigation permitting an exact study of such phenomena. The Blondel type of oscillograph enables frequencies of 3000—5000 cycles per second to be recorded without difficulty; by the use of a special construction it is possible to extend the range of application up to 15,000—20,000 cycles per second. At these frequencies, however, the error in the measurement of the amplitudes attains a value of almost 50 %. Even for this range and for frequencies up to several million cycles per second, it is necessary to resort to the cathode-ray oscillograph, where the

cathode beam has no inertia and permits frequencies of this order of magnitude to be recorded with sufficient accuracy, when the necessary precautions are taken.

With a Blondel oscillograph the tripping of the oscillograph and the deflection of the spot along the time axis can be effected mechanically due to the low speed of the phenomena to be recorded and relative minor importance of the delay in tripping.

The phenomena studied with a cathode-ray oscillograph occupy, on the contrary, times varying practically between several tenths to tens of microseconds. The inertia of a mechanical relay would be far too high to trip the oscillograph and the time sweeping circuit in a time interval of 0,1 to 0,2 μs. Only an electronic relay using thermionic valves the inertia of which can be made negligible by a suitable arrangement of circuits permit a sufficiently rapid tripping speed. In this article, particularly, the deflection of the beam along the time axis will be described. The time sweep must comply to the following conditions:—

1. The traverse of the beam must be a simple function of the time and independent of the phenomena investigated, of its duration and of its amplitude.

2. The speed of the time sweep must be variable within a wide range to render it as adaptable as possible to the phenomena studied; it is advantageous that it be also as constant as possible along the time axis to enable the same precision of time measurement to be obtained throughout the entire deflection.

3. The time sweep must be effectively tripped by the wave itself in a time interval as short and constant as possible (of the order of several 1/10 μs), the consistency of this tripping time being essential for the study of wave propagation. For the latter it is necessary that the instant the surge begins to travel along the test line should be rigorously defined, all the times being measured as displacements from this time origin.

4. It is necessary that the time sweeping device should be screened from electromagnetic and electrostatic influences which may be induced by the phenomena studied and which may superimpose harmonic oscillations on the normal time sweep.

5. For a surge generator which produces automatically one wave a second, it is essential that after the discharge the entire system automatically returns to its initial state in a time interval less than the interval between two successive discharges. In the time-sweeping system described, a condenser C is discharged through a screen-grid valve T_3 (Fig. 3), the screen grid is maintained at a constant potential V_{ge} by the battery B_p. It is well known that for such a valve the anode current i_a as a function of the anode voltage V_a has a characteristic as shown in Fig. 1, this current remains almost constant for voltages higher than the grid voltage V_{ge}. When the anode voltage drops below the voltage V_{ge} of the screen grid, then the anode current is reduced to a very low value.

Accordingly, when a condenser charged at a potential Vo is discharged through the anode circuit of such a valve, the curve of its terminal voltage as a function of time will be as shown in Fig. 2; it is practically a linear function of the time as long as $V_o > V_{ge}$. This voltage applied to the plates of a cathode-ray oscillograph will give a deflection which will be directly proportional to the time. The slope of the curve AB, which determines the speed of the time sweep, is inversely proportional to the capacity C and proportional to the current i_a, the latter is only dependent on the voltage of the screen grid of the valve T_3. The speed of the time sweep is thus determined by the adjustment of these two constants so that by this means condition 2 is fulfilled.

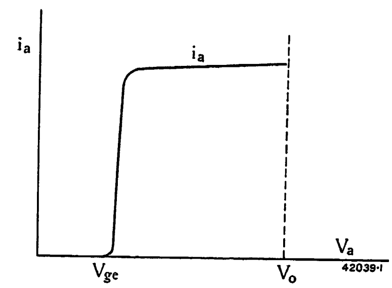

Fig. 1. — Characteristic curve of the anode current as a function of anode voltage.
(Screen-grid valve.)

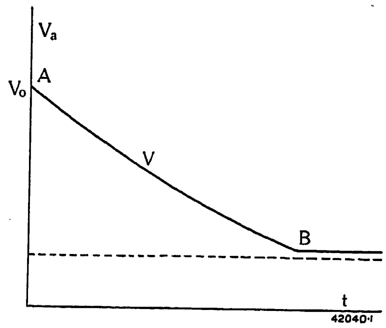

Fig. 2. — Condenser discharge through a screen grid valve. Curve of the anode voltage as a function of the time.

The schematic connections of the valve T_3 are shown in Fig. 3. The cathode-ray

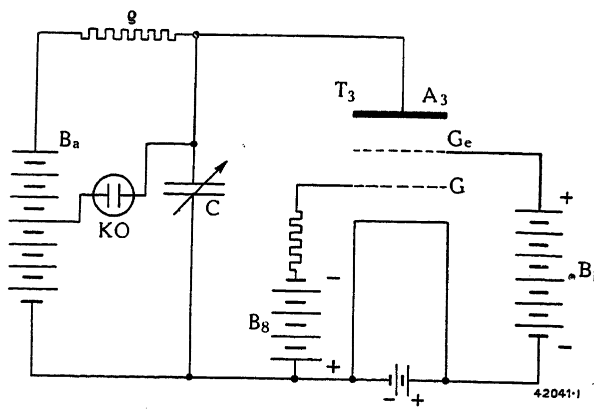

Fig. 3. — Schematic connections of the discharge valve.

Bg. Grid bias battery.
Ba. Anode battery.
Bp. Screen-grid bias battery.
C. Discharge condenser.
ϱ. High resistance (100,000—200,000 ohms).
KO. Cathode-ray oscillograph.

oscillograph KO is connected between the anode A_3 and the mid point of the anode battery Ba. In this way the voltage across the plates changes from a positive to a negative value; the time sweep is then symmetrical about the zero point. In the initial position the main grid has a negative polarity, the valve T_3 is blocked and the condenser C cannot be discharged. This arrangement is connected to an electronic relay which raises the main grid G to a positive potential and trips the time sweep when the surge is applied.

Fig. 4 shows the connection of the electronic relay for negative surges. The relay consists of a thermionic valve T_1 and a screen grid valve T_2. In the initial state a current of approximately 20 mA passes through the valve T_1 due to the high positive potential of the grid G_2 and because the grid G_1 is connected to the negative terminal of the filament. The anode current of the valve T_2 is zero, due to the negative potential of the grid G_3. The voltage distribution for the entire circuit as well as the currents in the different parts of the circuit are indicated in Fig. 4 by vertical numbers.

a) *Tripping the relay.*

Consider the sudden application of an impulse to the grid G_2 of the valve T_1, the impulse being sufficiently high to bring the grid G_2 to a negative potential; this is accomplished by means of a capacity c in series with an aerial A electrostatically coupled with the line along which the wave travels. The anode current of the valve T_1 immediately[1] ceases to flow and the anode voltage is raised from 150 to 250 V. This sudden increase in voltage will be transmitted by means of the capacity C_1 to the grid G_3 of the valve T_2 which thus becomes positive. Because the grids G_3 and G_4 are positive, a current of approximately 10 mA flows in the anode circuit (resistance R_4) of the valve T_2. As a result the anode voltage of the valve T_2 sinks suddenly from 250 to 200 V. This potential drop is transferred by the capacity C_2 to the grid G_1; the latter is thus brought to a negative potential (approx. — 50 V)[1]. The sudden change of the anode voltage of the valve T_1 is transmitted between the grid G_3 and the main grid G of the valve T_3; the latter becoming positive permits the discharge of the condenser C as previously described. As soon as the grid G_1 is charged negatively (approx. 0,2 μs after the incident of the impulse) any occurrence of voltage oscillations on the grid G_2 have no further influence on the relay:—the valve T_1 is blocked by the grid G_1 as long as the condensers C_1 and C_2 are charged and even a high voltage applied to the grid G_2 can not free the valve T_1. Therefore, the voltage fluctuations on the different parts of the relay are independent of the impulse voltage on the grid G_2, assuming that its amplitude is high enough to raise the grid G_2 to a negative potential and release the valve T_1. The first condition is then fulfilled.[2]

b) *Return to the initial state.*

During the whole time of discharge of the condenser C corresponding to the desired speed of the

[1] For simplicity the tripping will be considered as instantaneous; in reality it requires a measurable time interval depending on the time constants of the different circuits (capacities and resistances); the total tripping time amounts to 0,2 μs.

[1] The numbers in italic, Fig. 4, represent the values of the voltages after operating the relay.

[2] This explanation of the tripping of the relay is simplified in comparison with the actual process; in reality the sudden increase and decrease of the voltage will be to some extent reduced due to the grid currents which flow in the different grid circuits.

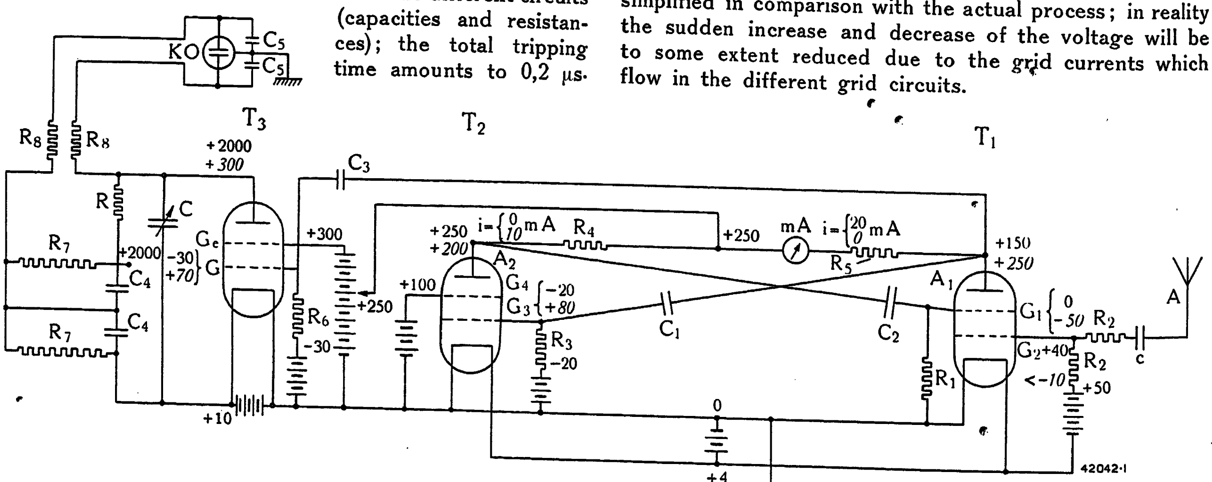

Fig. 4. — Schematic connections of the electronic relay.

T_1, T_2, T_3. Thermionic valves.
R_1, R_3, R_6. Leakage resistances.
R_2, R_4, R_5. Anode or space grid resistances.
R. Resistance for charging the capacity C.
R_7, R_7, C_4, C_4. Potential divider.
R_8. Damping resistances.
C_1, C_2, C_3. Coupling capacities.
C. Discharge condenser.
C_5. Damping condenser.
KO. Cathode-ray oscillograph
A. Aerial.
c. Coupling capacity of the aerial.
mA. Milliamperemeter.

time sweep and only amounting to several micro-seconds, the charging voltage of the condensers C_1, C_2, C_3, remains practically constant. Due to the positive charge of the grid G_3, the condenser C_1 is discharged partly by the grid current of the valve T_2 and partly by the discharge resistance R_3. As the potential of the grid G_3 falls, the anode current of the valve T_2 drops at the same time; this causes an increase in the anode voltage A_2 which is transmitted by the capacity C_2 to the grid G_1. As soon as the anode A_2 and the grid G_1 are raised to their original voltages corresponding to the drop of voltage of the grid G_3 then the relay is again ready for tripping.

The time required for the return sweep depends in the first place on the value of the capacity C_2, the grid current of the valve T_2 and the value of the discharge resistance R_3. For the relay described, this time interval is of the order of 1/3 s. By this means condition 5 is fulfilled.

To reduce the influence of disturbances produced external to the relay, the entire system is enclosed in an earthed case as shown in Fig. 5; only the batteries are connected outside the screen. In order to prevent any possible disturbances due to the external arrangement of the batteries, the leads are shunted by high capacities inside the earthed screen. The length of the connection between the cathode-ray oscillograph and earth can also cause disturbances in the time sweep. To eliminate these disturbances, the discharge circuit is not connected directly with the plates for the time sweep but through two damping resistances R_8, which are shunted by two capacities C_5, placed directly on the metal casing of the oscillograph, the mid point being connected to the metal casing. These precautions against disturbances make it possible to oscillograph waves of several hundred kilovolts free from distortion, in spite of the fact that they travel along a line only 15 m distant from the relay. Condition 4 is thus fulfilled.

c) *Additional magnetic-time sweep.*

In the system used, the cathode beam is switched on once a second for a period of 1/200 s and the surge testing plant is artificially synchronized with the beam.[1] The period during which the beam is switched on is thus considerably higher than the total time for the time sweep (up to approx. 100 µs). If no additional deflection were employed, the beam would remain still for a comparatively long time interval and make a black mark on the photographic plate. To prevent this fogging a slow-speed magnetic deflection is superimposed on the electrostatic deflection, in order to move the cathode beam outside the range of the photographic

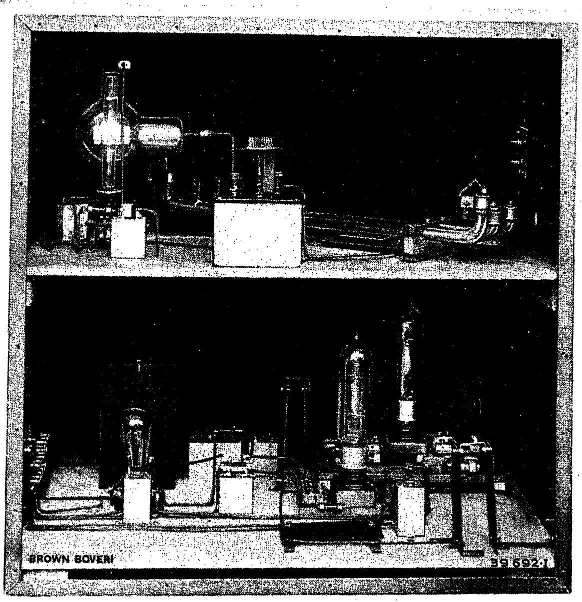

Fig. 5. — View of the electronic relay.

plate before and after the time sweep. An oscillogram recorded with this arrangement is shown in Fig. 6. From A to O the magnetic time sweep is of the order of 5 mm per 1000 µs; from O to B the time sweep is high and attains 1—20 mm/µs (i. e. 200—4000 times higher than between A and O), due to the superposition of the magnetic and electrostatic systems; from B to C only the magnetic time sweep is again effective (approx. 5 mm per 1000 µs). The fogging of the photographic plate is thus prevented.

The electronic relay as well as the combined time sweep thus satisfies all the necessary conditions. The recording of an oscillogram by this means can be summarized as follows. At time t = 0 the beam is switched on (cathode voltage) at the same instant as the magnetic deflection. The beam traces the straight line AO on the photographic plate with a low time sweep (approx. 5 mm per 1000 µs). At the instant when the cathode beam reaches O, the surge testing

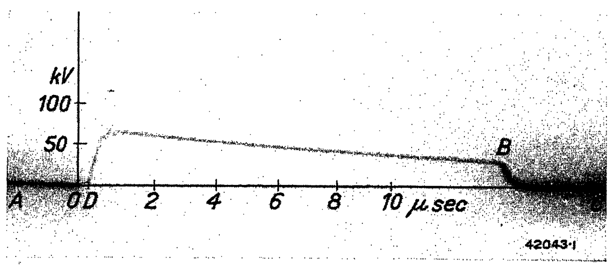

Fig. 6. — Wave recorded by means of the electronic relay.

A. Incidence of the beam on the photographic plate.
AO. Slow-speed time sweep (0·005 mm/µs).
O. Instant of operating the relay.
OD. Time taken by the voltage wave to travel along the transmission line.
OB. High-speed time sweep (6 mm/µs).
BC. Slow speed time sweep (0·005 mm/µs).

[1] See Kopeliowitch: Impulse tests. C. I. G. R. E. 1931, Vol. II, p. 77.

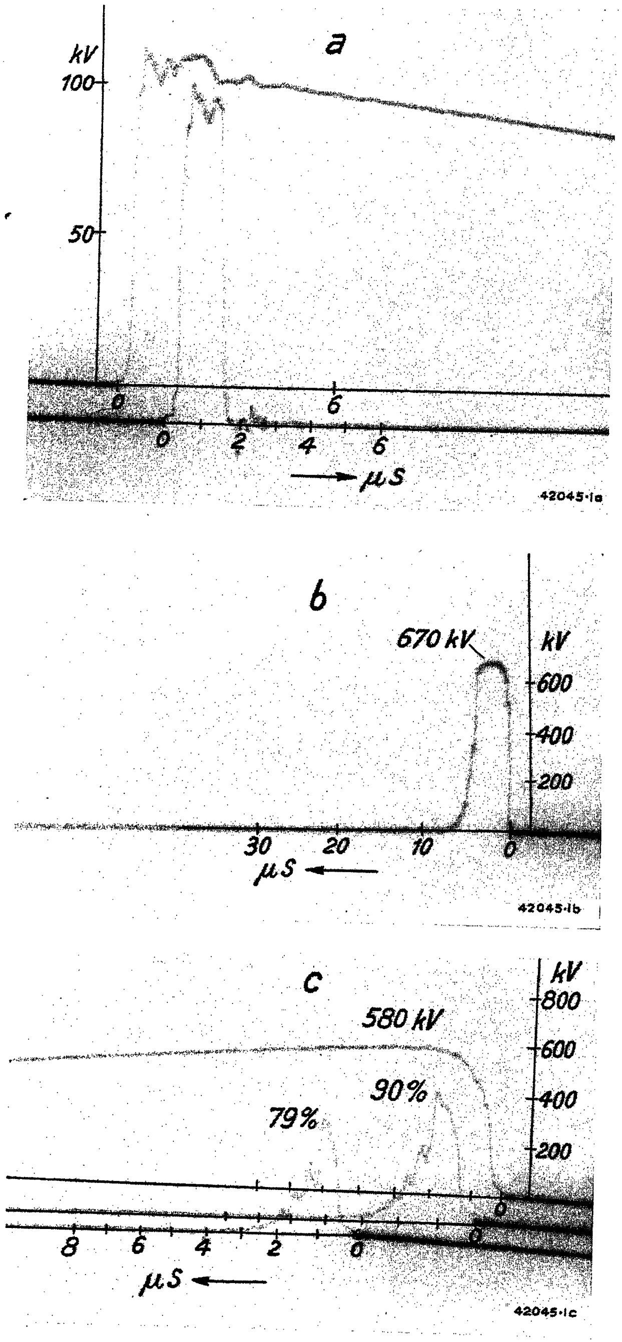

Fig. 7. — Investigation of potential dividers.
a. Potential divider with low time constants.
b, c. Potential divider with high time constants.

plant operates and a surge travels along the 150-m line. As soon as the wave reaches the beginning of the line, the relay is tripped by the aerial A coupled with the line and the electrostatic sweep (speed 1—20 mm μs) begins and reaches its normal speed in approx. 0·2 μs. When the wave reaches the end of the line (time interval 0·5 μs) the time sweep has already operated for 0·3 μs and the cathode beam has reached D. At this instant the voltage wave is applied to the deflection plates at right angles to the time sweep plates by means of a potential divider and the beam traces the time diagram of the voltage at the end of the line. At B the rapid time sweep is finished and the slow time sweep operates between B and C. From C onwards the ray is no longer on the photographic plate.

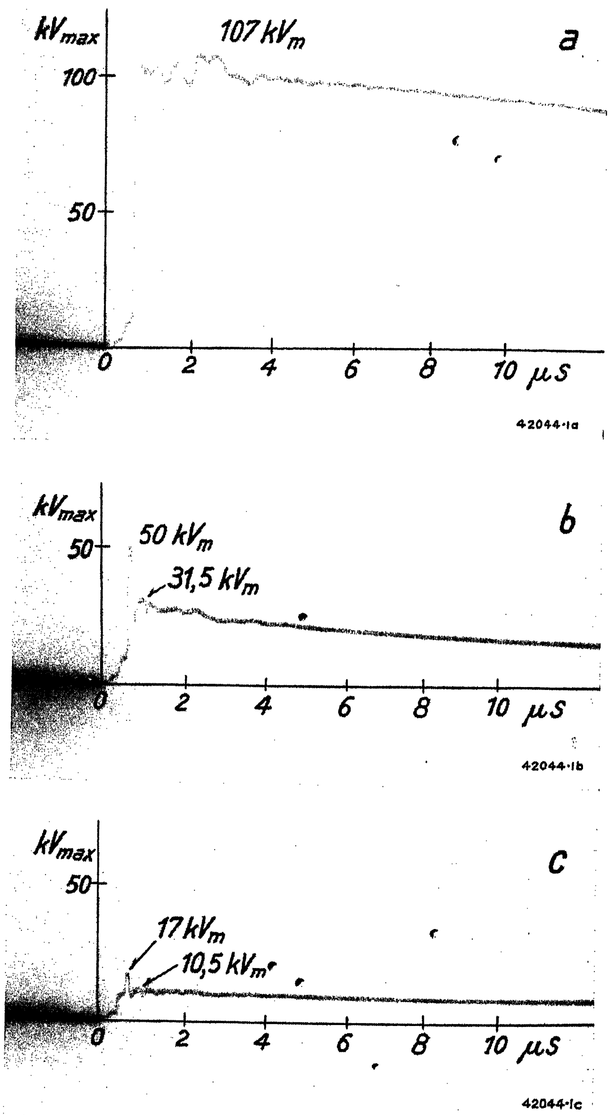

Fig. 8. — Investigation of the performance of lightning arresters.
Oscillograph record of the wave and the spark-over of a sphere gap.
a. Wave reflected at the end of the transmission line.
b. Wave reduced by a lightning arrester, rated voltage 5 kV, with a large time lag and high resistance.
c. Wave reduced by a "Resorbit" lightning arrester, 3·7 kV rated voltage.

The oscillograms reproduced in Figs. 7 and 8 show the regular operation of this system of time sweeping even when voltage peaks of very short duration (0·1 to 0·2 μs) have to be recorded.

(MS 921) *P. Fourmarier. (J.K.B.)*

THE KLINGNAU POWER STATION.

Decimal index 621.311.21 (494).

IN the year 1929, a company, the "Aarewerke A. G.", was founded, with head offices in Brugg (Switzerland), the object being to build and operate two hydro-electric power stations, namely "Wildegg-Brugg" and "Klingnau", both on the river Aar. The share capital of Fr. 30,000,000 was raised in common by Canton Aargau and the Aargauische Elektrizitätswerk together, 35 %; the Nordostschweizerische Kraftwerke A. G., the Motor-Columbus A.-G. and the Bernische Kraftwerke A.-G., together, 30 %; the Rheinisch-Westfälische Elektrizitätswerk A.-G., 30 %, and the Schweizerische Kreditanstalt 5 %.

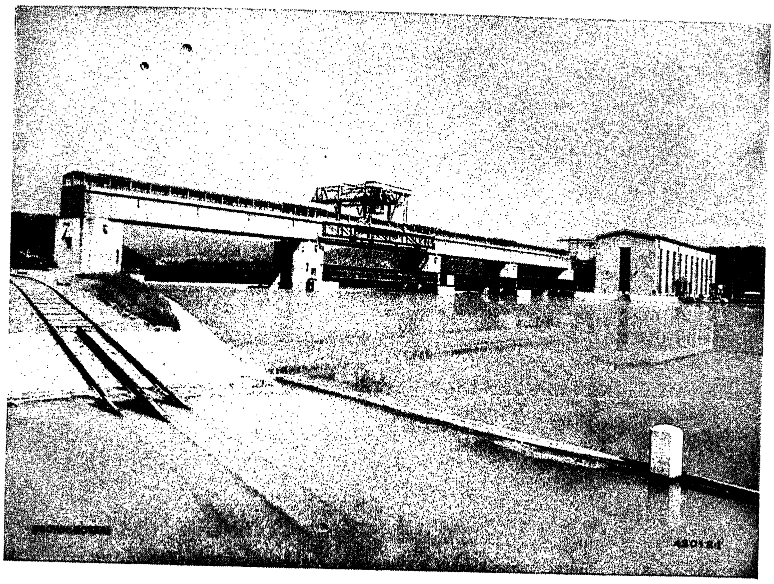

Fig. 1. — The Klingnau power stations with the sluice-gates, seen from the head-water side.

It was decided to begin with the building of the Klingnau power station and work on this plant was begun in the autumn of 1931; the station being put into service progressively as the generators were put up one after the other, in the course of the spring of 1935.

This power station utilizes the last seven kilometres of the river Aar, between the Beznau power station and the mouth of the Aar into the Rhine, the head available amounting to 5—7·6 m. At the beginning, a head-race channel type of station had been contemplated, but it was finally decided to build the station across the river itself, the machine hall forming a continuation of the sluice-gate bridge; this solution created a storage lake above the station 500—600 m wide and having a surface of about one to one and a half square kilometres.

The sluice-gate structure contains four sluice-gate openings each 30 m wide. The electric driving gear of the gates with automatic float control was delivered by Brown Boveri.

The machine hall on the right bank of the Aar contains three vertical-shaft Kaplan-type turbines each of 217 m^3/s absorption capacity developing 18,000 H.P. at 75 r.p.m. The generators built by Brown Boveri are direct-coupled to the turbines and each is designed for:—

Rated output . .	19,500 kVA
Power factor . .	0·7
Voltage . . .	10,500 $\pm$ 6 % V
Frequency . . .	50 cycles
Speed	75 r.p.m.
Flywheel effect .	$GD^2 = 8{,}900$ t.m^2

The pole wheel with shaft weighs about 165 t and has a diameter of 9 m. It is composed of a spider, in two parts, built of cast steel and to which the rim of the wheel, in four parts, is bolted. There are 80 poles secured by bolts to the rim of the wheel. The wheel once completed, was subjected to an over-speed test at 162 r.p.m. in the Brown Boveri shops. The stator is completely encased in a sheet-metal cover

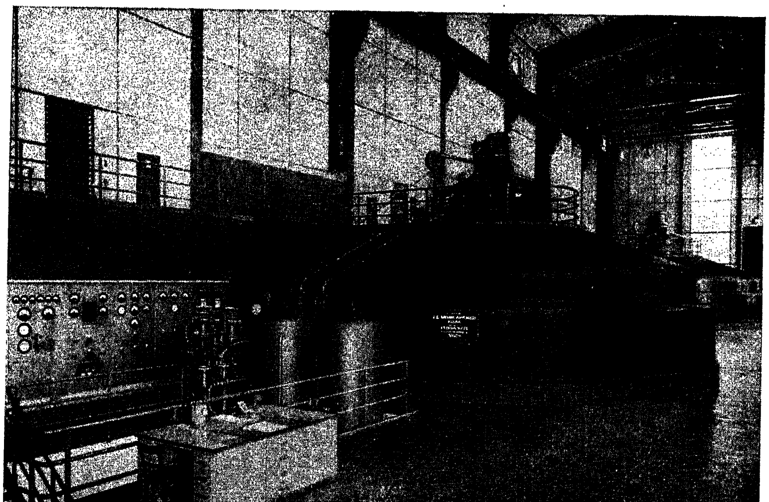

Fig. 2. — Part view of machinery hall of the Klingnau power station.

which comes right up to the wall of the machinery hall on one side and serves as collecting duct for the cooling air. The amount of cooling air required amounts to about 30 m^3/s. The upper bearing spider, on which the thrust bearing and the exciter are mounted, has six arms. It must support the downward thrust due to the water in the turbine as well as that due to the weight of the generator rotor and of the turbine wheel and this amounts to about 550 t when the unit is running. The lower spider carries the lifting jacks, for supporting the rotor during thrust-bearing dismantling; it also carries the brakes. The latter are worked by compressed air taken from the air reservoirs belonging to the pressure-oil system of the turbine governors. These brakes allow of bringing the rotating masses to rest, from their full-rated speed, within five minutes.

The exciters are of the built-on type, 220 kW, 250 V. Each exciter is equipped with a pilot exciter which allows of stable voltage regulation down to the lowest excitation required; this arrangement is necessitated by the working conditions of the Klingnau station, the practically entire output of which is supplied to very long high-voltage transmission lines. The pilot exciters deliver about 10 kW at 120 V, each, and are flat-compounded:— i. e. work with constant voltage. Regulation is carried out by means of the new Brown Boveri high-power quick-acting regulator which can also be used as a field rheostat for hand regulation. Exhaustive tests at taking over proved how well this regulator works; it has a very wide regulating range and gives excellent stability at every load, further it is characterized by great regulating rapidity, when circuit breakers open or when load fluctuations occur.

The importance of the automatic voltage regulation of the sets, which are subject to rapid speed increases, is shown by the fact that a speed increase of the set of 25 % produces a voltage increase of the pilot exciter of 75 %.

The generators are also equipped with the usual protective devices such as over-current protection, excess voltage protection, differential protection and earthing protection for stator and rotor circuits. A temperature-indicating equipment allows constant supervision of the temperature of the windings, the bearings, the air and the transformers; it also gives automatic alarm when excessive temperature rises occur.

All control apparatus, relays and measurement-instruments are placed on an 11-panel and 8-panel switchboard which is mounted beside each machine. The board of generator 1 also carries the apparatus for the general distribution for the auxiliary services while the board of machine 3 carries the water-level remote indicator and the remote control for the sluice-gate plant.

Each generator is direct-connected to a main transformer without passing through bus-bars or circuit breakers. The transformers are of out-door type and provided with oil conservators secured to the wall of the machine hall. There are cooling pipes all round the oil tank which are amply sufficient for self-cooling.

The transformers are each built for:—
Rated output 20,000 kVA;
Connections star/delta.

Voltage ratio, under no load:—

1st transformer 10,500 ± 5 %/145,000 V, which can be changed over to 10,500 ± 4%/116,000 V;

2nd and 3rd transformers 10,500 ± 5 %/145,000 V, which can be changed over to 10,500 ± 4 %/116,000 V and to 10,050 ± 4 %/55,500 V.

The reversing of coil ends on the tappings on the low-voltage winding and the change over from

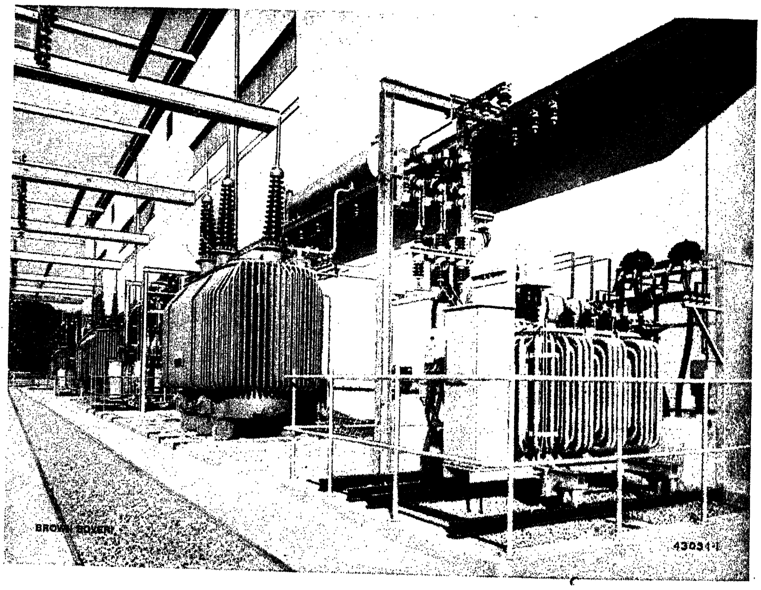

Fig. 3. — Transformer plant.

145 kV to 116 kV have to be carried out the transformer being dead by means of tapping switches which are built in but are operated from outside. The change over from 116 kV to 55·5 kV, on the second and third transformers, is done by parallel connecting of the two halves of the high-voltage winding.

It is worthy of note that these 20,000-kVA, 145-kV transformers built for natural oil cooling were delivered from the shops and carried to the plant filled with oil; this was possible thanks to the tubular design. After the carriage which supports the tank, the bushings and the safety valve had been removed, the transformers were loaded on to a specially low platform truck belonging to the Rheinisch-Westfälisches Elektrizitätswerk and taken by rail to the plant. Thanks to this, erection in the plant itself was carried out in a fraction of the time generally required for such big units as these.

There are also three auxiliary transformers in this station, one per generator and connected thereto through an oil circuit breaker. These auxiliary transformers are built for:—

1st transformer:—

Voltage ratio under no load 10,500 $\pm$ (8 $\times$ 132)/400/8400 $\pm$ 4 % V;

Connections star/star/delta;

Rated output 500/500/500 kVA.

2nd and 3rd transformers:—

Voltage ratio under no load 10,500 + (8 $\times$ 132)/400 V;

Connections, star/star;

Rated output 500 kVA.

These transformers are also self-cooling units of the tubular type, the oil conservators being built on. They have the Buchholz protective equipment.

The auxiliary transformers supply the auxiliary requirements of the station at 380 V; the three-winding transformer will, later, be connected through its third winding to the 8-kV system of the Aargauische Elektrizitätswerke.

As the voltage of the generators is subjected to very big fluctuations, on account of the power delivered to the system of the Rheinisch-Westfälisches Elektrizitätswerk, the auxiliary transformers are provided with equipment for voltage regulation under load. This regulation is carried out on the 10·5-kV winding and allows the auxiliary station service to be supplied at a constant voltage despite the fluctuations of voltage on the transmission lines. The regulating windings, the connections of which can be reversed, are subdivided, on each phase, into eight equal sections, the conductor ends being brought to the main contacts of the built-in, three-pole star-delta switch which is immersed in the transformer oil. The sparking contacts and step resistors are not oil-immersed and are located at the top of the step switches which are designed as bushings. The step switches are controlled by motor drives built-on to the transformer carriage. These drives are remote-controlled by push buttons from the control room. The motor drives are equipped with spring-type power-storage devices which intervene if there is a danger of the step switch being immobilized between two steps, owing to a failure of the voltage from the auxiliary source supplying the motor drives.

As the principal duty of the Klingnau station is the supply of power to the system of the Rheinisch-Westfälisches Elektrizitätswerk, the design of the high-voltage switchgear could be made very simple. A 116-kV outgoing line takes off from each transformer, after passing through circuit breakers and disconnecting switches, and is carried to the Thiengen substation of the RWE 5 km away, where paralleling is carried out. In order to be able to supply the Swiss system with power, as well, at a later date, a 50-kV set of bus-bar is mounted, which, however is designed for 145 kV and, therefore, can also be operated at that voltage. The lines going to the Swiss system will take off from this set of bus-bars.

The possibility of having to supply two separate systems alternatively makes certain demands on the power-measuring equipment. There are two double sets of meters for active and for wattless power, one set being for the "RWE" service and one for the "Swiss" service. The change over is automatic and by means of auxiliary contacts on the disconnecting switches. A mark on the registering wattmeter allows of ascertaining, with certainty, on which network system any one machine is working.

The Thiengen Substation in the Black Forest is of the outdoor type and to it come the power lines from Klingnau as well as from the Albbruck-Dogern and Schluchsee power stations. It is proposed to lead power to it, later, from the Brugg-Wildegg station. The power available is stepped up from 116 to 220-kV and carried to the industrial region of Rhenish-Westphalia by a double transmission line which is, also, linked in Herbertingen to the 220 kV line coming from Bludenz in Austria. This line which stretches from the Vorarlberg, in Austria, to the Dutch frontier is designed for 380 kV and is to work at this voltage, at a later date. Thus, the Klingnau power station and, with it, the Albbruck-Dogern and Schluchsee stations as well as the Parthennen station in the Vorarlberg, work in parallel with the big thermal power stations in the Rhenish-Westphalian industrial region, which leads to very satisfactory economic exploitation conditions and to the rational utilization of the various contributary power stations.

(MS 961) *W. Marolf. (Mo.)*

THE BROWN BOVERI SERVO FIELD-REGULATOR CONTROL FOR DIESEL-ELECTRIC VEHICLES.

Decimal index 621.337.1.621.335.0.33.44.

I.

OPERATING CHARACTERISTICS OF THE DIESEL ENGINE AND DEMANDS MADE ON THE ELECTRICAL POWER-TRANSMITTING EQUIPMENT.

THE Diesel engine develops a relatively constant torque at all speeds and its speed drops immediately under the effects of overloads. A given quantity of fuel injected per working stroke into each cylinder develops a quite definite torque which varies very little with the speed. If the quantity of fuel (admission) remains constant, it, therefore, follows that the output of the engine varies about proportionately to its speed, and full load can only be developed at full speed. For a given working speed, the power developed is, thus, a constant, dependent on the torque available.

In designing an automatic system of regulation for Diesel-electric sets for traction purposes, the peculiarities just enumerated must be taken into account.

(1) Suitable measures must be taken to prevent the Diesel-engine from being overloaded. In so doing, and without intervention on the part of the driver, the full output of the Diesel-engine must be available over the whole range of tractive efforts and vehicle speeds encountered and taking into account the fluctuation in power consumed for auxiliary services.

(2) In order to prevent unnecessary wear of the Diesel-engine parts, the engine must be made to run slower when power requirements for the vehicle are lower. In satisfying this requirement, it must also be possible to make adjustments to various partial loads at a constant engine speed, this by grading the torque, in order to attain a sufficient number of regulating steps. This is essential with such Diesel engines as can only run at two or three working speeds in order to avoid critical speeds. The possibility of being able to vary the load by grading the torque developed is, further, a valuable asset in traction Diesel engines in which occasional peak loads (starting trains, trains travelling on gradients) are encountered and can be met by increasing the fuel charge of the cylinders, while maintaining constant full engine speed.

(3) The electric transmission gear should be made as independent as possible of influences which may intervene to modify the curve and character of the external characteristics of the generator (changes in resistance of the exciter winding resulting from the machine heating up, Hysteresis, voltage fluctuations of the source of current supplying the separate excitation circuit of the main generator, etc.)

(4) Simple and reliable layout of the automatic regulating equipment must be striven after it being so designed that it can always be used with multi-control service; a definite position of the driver's handle must produce a definite constant output of the Diesel engine.

Technical publications have given detailed descriptions of the different systems of automatic control used and of the adaptability of the electric transmission to the running conditions of the Diesel engine and to traction-service requirements which these systems allow of attaining.[1] The *servo field-regulator control* developed by Brown Boveri, which is described herewith, is characterized by very perfect attainment of all the essential conditions set out in the preceding paragraphs.

II. GENERAL LAYOUT AND METHOD OF OPERATION OF THE SERVO FIELD-REGULATOR CONTROL.

This system of control is based on the classic Ward-Leonard connection, in which the voltage of the main generator and also its output for a given constant speed maintained by the centrifugal governor of the Diesel engine can be modified by acting of the separate excitation of the said generator. It is advantageous to build the main generator with a double excitation system, that is to say with auto-excitation and with separate excitation, in order to allow of reducing the strength of that fraction of the excitation current which has to be regulated; this allows of having relatively low separate excitation outputs and correspondingly small regulating apparatus, even when the output of the main units is considerable.

Fig. 1 shows the general layout and connections of the electric transmission and regulation. Figs. 2 and 3 show the design of the servo field regulator for the 410-H.P. Diesel-electric motor coaches of the M. Z. A. Railway, Spain (Madrid-Saragossa-Alicante)[2].

The output of the Diesel engine is set by the driver by means of the driving handle and this output adjusted to is maintained constant by the servo field regulator without further intervention on the driver's part. The field regulator 11, which switches in and out the regulating resistors 12 inserted on the separate-excitation circuit of the main generator, is actuated by servo-motor 6 (thence the designation "servo field regulator"). The working piston of the servo-motor is under oil pressure and maintained in equilibrium by the counter thrust of a spring. The regulating valve 7 regulates the in and out flow of the oil under pressure. The chief characteristic of the servo field regulator control is that the main influencing of the servo-motor is by direct mechanical

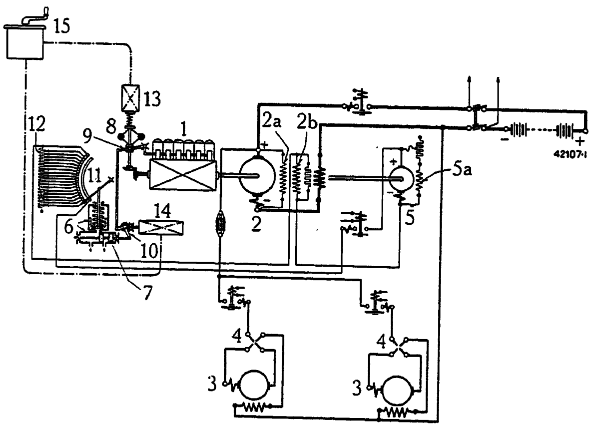

Fig. 1. — General diagram of connections for electric power transmission with Brown Boveri servo field regulator control.

1. Diesel engine.
2. Main generator.
2a. Auto-excitation shunt winding.
2b. Separate - excitation shunt winding.
3. Traction motors.
4. Commutating switch.
5. Auxiliary generator.
5a. Shunt winding, auto-excited.
6. Servo-motor.
7. Regulating valve.
8. Centrifugal governor of Diesel engine.
9. Fuel-pump control rod.
10. Connecting lever between fuel-pump control rod and regulating valve of servo-motor.
11. Field regulator.
12. Regulating resistance in the separate-excitation circuit 2b of the main generator.
13. Speed adjustment device for the Diesel engine.
14. Torque-adjustment device on servo field regulator (with cam, according to Figs. 2 and 3 or with electro-magnet according to Fig. 4).
15. Control handle for driver.

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[1] See:— Elektrische Bahnen, Fachheft: Diesel-elektrische Triebwagen, Nov. 1934.— Bulletin de l'Association du Congrès des Chemins de Fer, May, 1935: Contribution à l'étude comparée des divers systèmes de transmissions électriques utilisés dans les automotrices Diesel-électriques.

[2] The Brown Boveri Review, year 1934, No. 10, page 185.

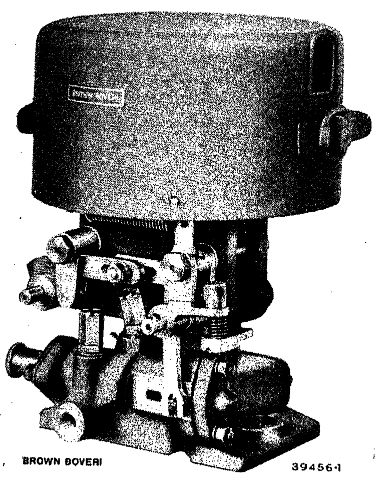

Fig. 2. — Servo field regulator designed to be built in with a 410-H.P. Maybach Diesel engine.

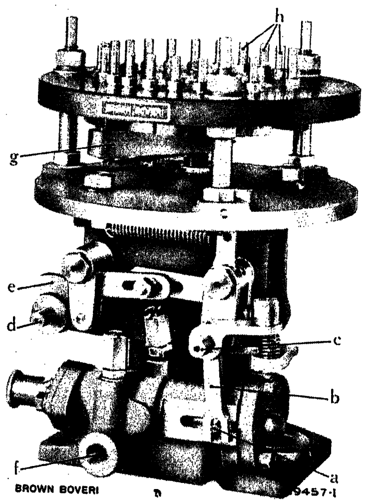

Fig. 3. — Servo field regulator without the cover of the field regulator.

a. Point of attack of the regulating valve.
b. Actuating lever of the regulating valve.
c. Shaft end to which the fuel-pump control rod is connected.
d. Shaft end to which the torque-adjusting device is connected.
e. Cam rigidly connected to shaft end d.
f. Compressed oil inlet (the compressed oil outlet is below and invisible in the illustration).
g. Contact brush for regulating resistance.
h. Connecting terminal for regulating resistance.

means, namely by the control rod 9 of the Diesel-engine fuel pumps. At a given speed, the position of the sleeve of the centrifugal governor — that is the setting of the control rod of the fuel pumps — gives an exact measure of the output the Diesel engine can give. Every change in load from the state of equilibrium calls for a movement of the fuel regulating rod. If the output of the Diesel engine is to be maintained constant, the deviation of the sleeve of the centrifugal governor from its position of equilibrium must initiate a corresponding change in the excitation of the main generator. The mechanical connection 10 between the control rod of the fuel pumps and the regulating valve of the servo-motor is, therefore, so adjusted that the regulating valve is closed, that is to say the field regulator is left unchanged, when the control rod of the field pumps is in that particular position for which the generator set puts a load on the Diesel engine corresponding to the load setting dictated by the driver's lever. Any increase in the load of the main current (traction) circuit as compared to the position of equilibrium causes oil to escape and brings about a reduction in generator excitation; a decrease in the electric load causes an inflow of oil and an increase in the excitation of the generator.

The adjustment process goes on until the adjusted working speed of the engine and the torque belonging thereto have been re-established. The power taken by the main generator is then identical to that before the adjusting process took place, but with current and voltage values which have changed in order to meet the new travelling conditions.

According to the description just given, the servo field regulator regulates, in short, to a constant maintenance of a given position of the control rod of the fuel pumps or to constant fuel charge injected. Under proper working conditions of the Diesel engine this corresponds to maintenance of a constant torque, which again, for a given working speed, means maintenance of the engine output. It is a characteristic of this kind of regulation, that the momentary setting of the control rod of the fuel pumps is an exact measure of the *power of the Diesel engine available.* Thanks to this method of operation, all irregularities in the way the Diesel engine works are correctly taken into account. If one or more cylinder works intermittently or not at all (as a result of there being air in the fuel pipes), the servo field regulator prevents the other cylinders being overloaded, by reducing the total engine output until the position of the control rod of the fuel pumps again corresponds to admissible loads on those cylinders still operating. The control is also suitable to such cases as a change occurring in the power capacity of the Diesel engine taking place due to combustion phenomena (change in density of fuel air, quality of fuel, thermal efficiency, etc.); the load on the electric side adjusts itself to the new working conditions and the Diesel engine is not called to supply more power than it can give. An automatic load regulation on the wattmeter principle which would keep the output of the main generator constant would either lead to excessive overloading or to incomplete utilization of the Diesel engine, in such cases.

As was said, the regulating valve of the servo-motor must remain in the closed position as soon as equilibrium has been established between generator and engine load in accordance with the value set to by the driver's handle in the driver's cab. In order to fulfil this condition at any partial load as well as at full load, the shaft end c (Fig. 3), to which is attached the actuating lever b of the regulating valve, is displaced horizontally. According to the extent of this displacement, the actuating lever b has to pass through an angle which is greater or smaller in order to bring the regulating valve a to its closed position as referred to the angular displacement for full-load torque. This means that for bigger loads more fuel has to be injected and less fuel at smaller loads and correspondingly modified torques are transmitted to the generator set. If a torque value of about 70 % of the fuel charge at full load is adjusted to, when making a change in the torque grading, this gives the most economical point for Diesel-engine operation, as it corresponds to the most advantageous ratio between air volume drawn in and fuel quantity injected as referred to thermal efficiency.

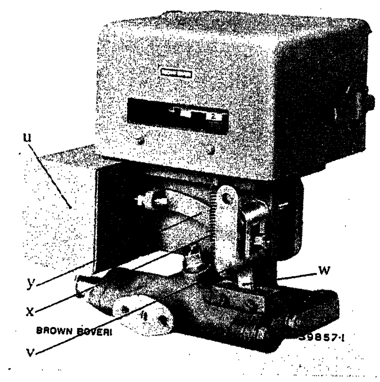

Fig. 4. — **Servo field regulator intended for building together with a 270-H.P. Sulzer Diesel engine.**
u. Electro-magnets for torque adjustment hidden by cover.
v. Fulcrum of actuating rod of regulating valve.
w. Actuating rod of regulating valve.
x. Spring.
y. Connecting lever.

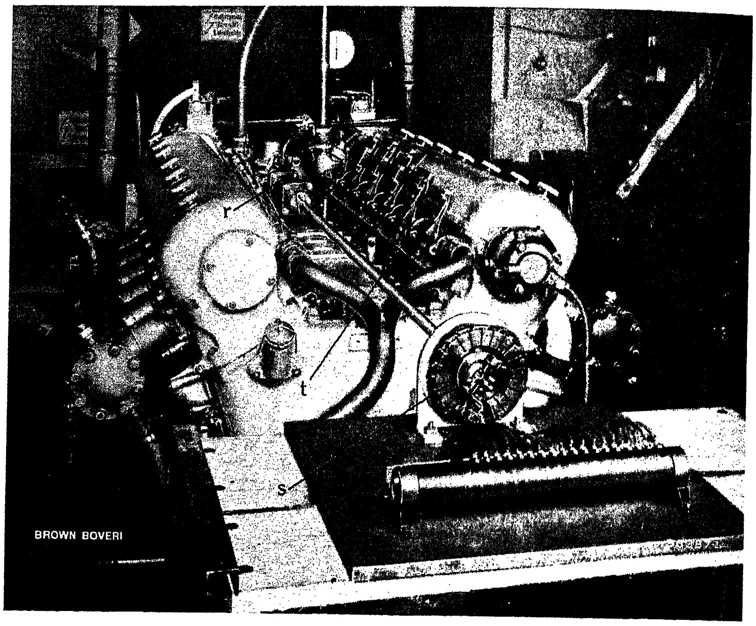

Fig. 5. — **Servo field regulator with separate servo-motor and field regulator (experimental plant).**
r. Servo-motor. s. Field regulator.
t. Connecting shaft between servo-motor and field regulator.

III. EXAMPLES TAKEN FROM REGULATING EQUIPMENTS BUILT.

The servo field regulator for the four motor coaches of the Spanish M.Z.A. Railway, according to Figs. 2 and 3 works combined with a 410-H.P. Maybach Diesel engine. The same type of servo field regulator is also placed on one of the motor-coach trains of the Dutch Railways; it has two 410-H.P. Maybach Diesel engines[1]. The working conditions of the Maybach Diesel engines allow of continuous speed regulation, but with definite torques developed at the different speeds (so that output in function of speed varies approximately as in a propeller characteristic). For this reason, the torque setting is coupled to the adjustment device for the spring of the centrifugal governor. The cam e rigidly connected to shaft d can be given any profile desired and can produce any horizontal displacement of shaft end c for a given Diesel-engine speed; thus, any torque prescribed by the Diesel-engine manufacturer can be produced at the speed worked to.

In the servo field regulators (Fig. 4) built for four Diesel-electric motor coaches of the Ferrocarril Provincial de Buenos Aires[2] and which work with 270-H.P. Sulzer Diesel engines, the regulating valve of the servo-motor is governed from above and not from the side. Further, as only four working speeds can be used, in this case — adjusted in quick steps by an electro-pneumatic device — an electro-magnetic torque-adjusting device has been adopted; this is controlled by the driver's handle. This torque-adjusting device consists of three electro-magnets lodged under the cover and by means of which the fulcrum v is horizontally displaced, by means of connecting lever y, in counter-sense to the influence of vertical spring x, placed on the left of fulcrum point v of lever w which governs the regulating valve.

In the servo field regulators shown in Figs. 2—4, the oil-pressure operated servo-motor part and the electric contact system of the excitation regulation are combined in a single apparatus, while, in the design shown in Fig. 5, the field regulator is mounted separately.

The table given herewith is a summary of the servo field regulators for Diesel-electric vehicles which have been delivered up-to-date by Brown Boveri or are now in course of completion.

No.	Name of railway and type of vehicle	Type of Diesel engine	Number of servo field regulators	Notes
1	Spanish M.Z.A. Railway, motor coach .	Maybach 410 H.P.	4	According to Figs. 2 and 3
2	Dutch Railway, motor coach train . . .	Maybach 2×410 H.P.	2	According to Figs. 2 and 3
3	German State Railway Co., motor coach	Maybach 410 H.P.	2	According to Figs. 2 and 3
4	Ferrovie Calabro-Lucane (Italy), motor coach . .	Saurer 2×127 H.P.	20	Design as in No. 1 but without torque adjustment
5	Ferrocarril Provincial de Buenos Aires, motor coach . .	Sulzer 270 H.P.	4	According to Fig. 4
6	Narrow-Gauge Railway Diekirch-Vianden (Luxembourg), motor coach . .	Deutz 200 H.P.	2	According to Fig. 4
7	—	Maybach 410 H.P.	1	Experimental equipment according to Fig. 5

(MS 943)

A. E. Müller. (Mo.)

[1] The Brown Boveri Review September/October 1933, No. 5, page 157: "Diesel-electric motor-coach trains for the Dutch Railways".

[2] The Brown Boveri Review January/February 1935, No. 1/2, page 35.

STAR-DELTA SWITCHES WITH THERMAL RELEASES, FOR CURRENT RATINGS OF 64 TO 400 A AND A VOLTAGE RATING OF 500 V.

Decimal index 621. 316. 765. 1.

THE star-delta method is the simplest and the cheapest one for starting squirrel-cage motors under a moderate starting current. The stator winding is delta-connected when the motor is running and star-connected while it is being started; this has the same effect as though it were connected to a supply voltage of about 58 % of its rated voltage, during the starting period. According to the design of the motor, the current surge at starting is reduced to between 1·5 and not quite 2 times the rated current, a value allowed by even very severe power-supply regulations. However it must be remembered that the starting torque is reduced to about 50 to 80 % of the rated torque, under these conditions, and this obviously limits star-delta starting to drives requiring a low starting torque only. The latter are so numerous, however, that a very wide field indeed is open to the squirrel-cage motor with star-delta starter even when excluding artificial aids of a mechanical kind in order to start up, such, for instance, as centrifugal couplings and drives through fast and loose pulleys.

Fig. 1 shows the current and torque curves when a star-delta starter is used. When the torque M⅄ developed by the motor at starting is equal to the load torque M_m of the driven machine, there is no more acceleration and the motor must be delta-connected in order to run it up to its full speed. This jump to the higher torque is, naturally, accompanied by a current surge which, as Fig. 1 shows, is all the shorter and smaller the quicker the change-over has been effected. This imposes on the star-delta starting gear the important condition for perfect motor operation that the change over from star to delta connection should not only be *properly timed* but should be *carried out quickly*, if heavy current surges are to be avoided.

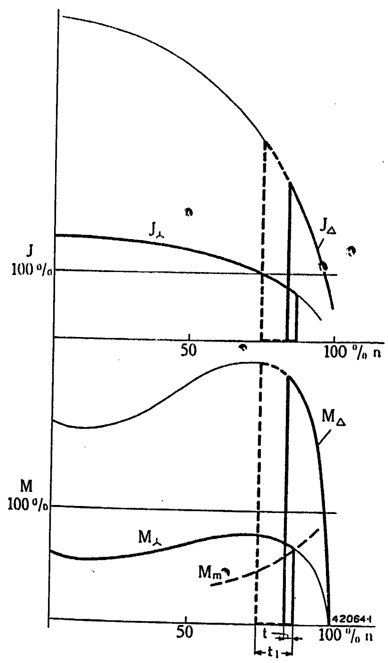

Fig. 1. — Starting torque (M ⅄, M Δ) and starting current (J ⅄, J Δ), in the star-delta starting process.

Mm. Starting torque required by machine being driven.

t, t1. Falling off in speed (r. p. m.) according to duration of the changing-over process.

With this end in view, Brown Boveri have designed their hand-operated, star-delta, motor-protecting switch in such a manner that a rapid change over of connections is obligatory and, if not complied with, results in the starting process being broken off. If the change over movement is too slow, a locking bar holds the switch handle as it passes through its switched-out position. This lock also prevents straight closing down of the switch in the running position, so that the starting process must take place in proper sequence of operations, namely, first by star connections succeeded by a rapid change over to delta connections.

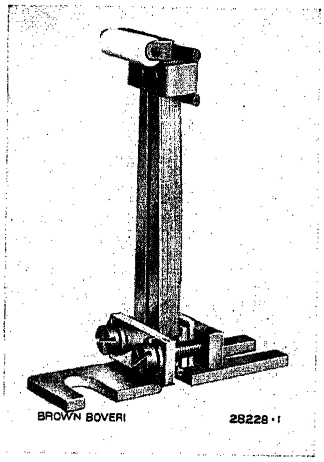

Fig. 2. — Brown Boveri thermal releases.

The star-delta switches, summarily described in the following paragraphs, have been developed from the existing switchboxes for motors with thermal releases and possess all the characteristics of the said switchboxes, namely:— a completely enclosed, dust and spray-water proof housing; a safety interlock between switch and cover, so the latter can only be opened when the switch is open, those parts which are then still under voltage being protected against accidental contact; a drive through a free-return clutch and a reliable motor protection by the well-known

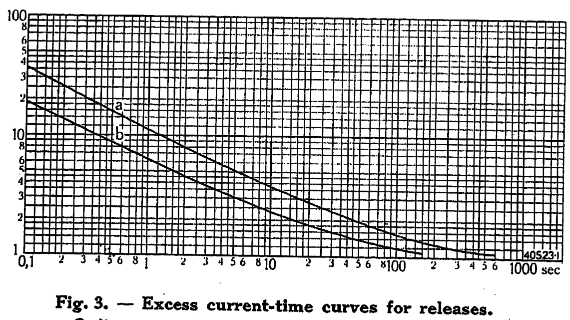

Fig. 3. — Excess current-time curves for releases.

Ordinates: — Multiple of motor current.
Abscissae: — Tripping time in seconds.
a. From cold condition.
b. From standard service temperature.

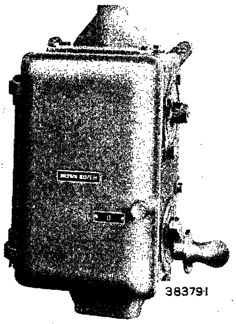

Fig. 4. — Star-delta motor-protection switch Type LCS 2e, 64 A current rating.

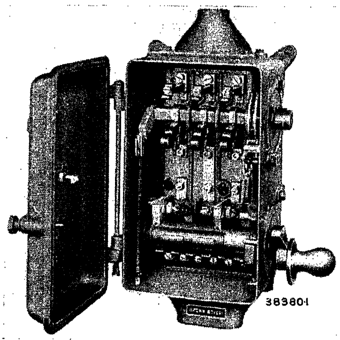

Fig. 5. — Star-delta motor-protection switch, Type LCS 2e, 64 A current rating. Switch open and sparking chambers removed.

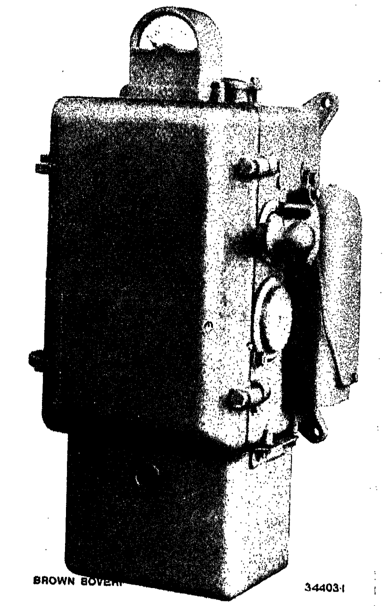

Fig. 6. — Star-delta motor-protection switch, Type MS 4 f, 125 A current rating.

Brown Boveri thermal releases. The star-delta switch thus combines perfect starting and switching to all the advantages inherent to a type of apparatus which has proved its value by years of practical use.

(a) *Star-delta switch Type LCS 2e for 64 A rating.* — The design of this apparatus is based on the well-known type of switchbox LC 2e and on the reversing type of switchbox LCU 2e. The rugged housing, both dust and spray-water proof, contains a three-pole switch with contacts in air, connected by a catch, in the usual way, to the rod of the thermal releases; it also contains a change-over drum for connecting the motor winding in star or in delta. If, now, the switch-lever handle is depressed, the drum connects the three phases of the motor in star and, only after this has been done, the main switch closes.

By quickly laying over the lever handle upwards, the main switch is momentarily cut out, the motor windings are connected in delta by the drum and then the switch is reclosed. The drum prepares the star or the delta connections but, always, under no current, which saves its contacts from wear. In order to attain the rapid change-over requisite to good starting, a locking rod is shot outwards when the speed of operation is above a given value, and this allows of operating the switch without hindrance. The very convenient lever handle makes rapid changing over an easy matter.

The star-delta switchboxes LCS 2e are delivered with two as well as with three thermal releases and with or without a low-voltage tripping device, also with or without built-on ammeter. The leads can be brought in through a conduit branch or through a double trifurcating box.

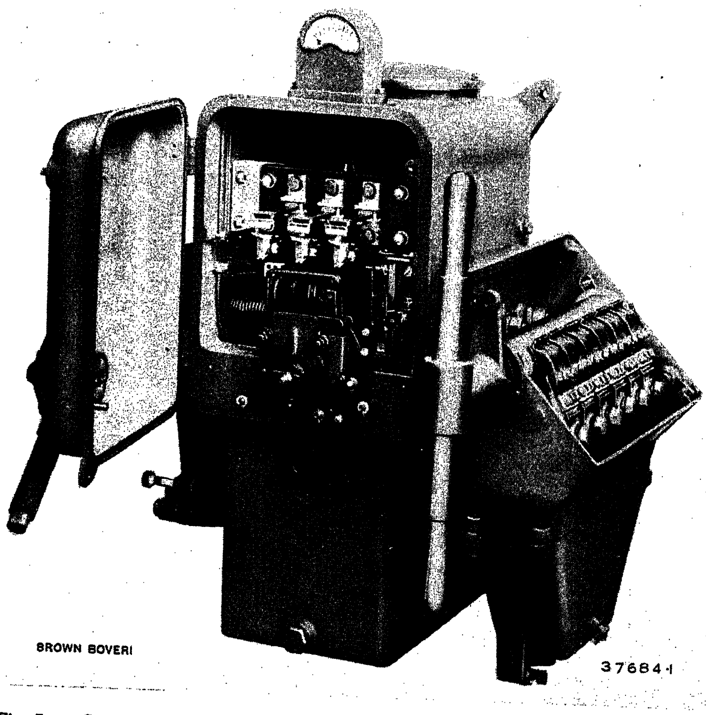

Fig. 7. — Star-delta motor-protection switch, Type MBS 8, 250 A current rating. Switch open.

(b) *Star-delta switch Type MS 4 f, for 125 A rating.* — The design of this switch has been evolved from that of motor switchbox Type M 4 f and only differs in its main characteristics from the 64-A star-delta switch by the contacts of the main switch being oil-immersed. This switch is also delivered

with or without low-voltage tripping device and with or without an ammeter. The thermal releases as well as the ammeter carry the whole motor current, there are no current transformers to step down the latter. The leads are brought in on either side of the switch-box, either by means of conduit branches or of trifurcating boxes which can be compound-filled.

(c) *Star-delta switch Type MBS 8, for 250 A and Type MBS 10 for 400 A rating.*—These switches are so designed that the star-delta change-over drum is built on in its own casing to motor switchboxes of Types MB 8 and MB 10, the design of which is unaltered. The drive of the main switch is taken over by the change-over drum. The contacts of the main switch are oil-immersed while those of the change-over drum are in air, as they only have to operate under no current. In the 250-A switch, the whole current passes through the thermal releases and ammeter while in the 400-A switch the latter are supplied through current transformers. These switches can be delivered with built-on ammeter, low-voltage release, electric interlocks to other apparatus, remote tripping and signal contacts and they can also be designed with short-circuit high-speed tripping. The leads are always brought in through compound-filled trifurcating boxes so that the switching apparatus is completely enclosed.

(MS 932) *S. Hopferwieser. (Mo.)*

NOTES.

Diesel-electric shunting locomotives of the simplest design.

Decimal index 621. 335. 3. 033. 44.

THE outstanding characteristics of the electric transmission of power in Diesel driven locomotives are:— smooth regulation without steps of both tractive effort and of speed, long life and great reliability. These qualities are the determining ones in the choice of electric transmission for Diesel shunting locomotives, in which trouble is often encountered when a mechanical drive is used, on account of the continuous changes in reduction ratio, causing wear of the transmission organs in spite of skilled and conscientious handling. For these reasons, electric transmission of power in Diesel-driven shunting locomotives is superior to all other systems of power transmission, even for very low-powered units. As, however, the advantages of the Diesel locomotive as compared to the steam locomotive would be nullified by the much higher cost of the former and as shunting locomotives are often driven and looked after by an unskilled staff, it becomes imperative to simplify their driving equipment, to as great a degree as is feasible. This is made easier in low-powered shunting locomotives, as in these units the condition imposed that the output of the Diesel engine be utilized to the utmost over the entire speed range can give precedence to a simplification of the electrical equipment.

As an example of a Diesel-electric shunting locomotive of the simplest design, the 82/90 H. P. unit being built at present by Brown Boveri and the Compañía Auxiliar de Ferrocarriles Beasain for the Junta de Obras del Puerto de la Coruña, is well worthy of note. This locomotive is shown in Fig. 1. It only measures 5·2 m over buffers and weighs 20 t, while developing a maximum starting tractive effort of 5250 kg, and a continuous tractive effort of 2000 kg. The rated shunting speed was to be between 5, and 10 km/h and the maximum speed specified for was 15 km/h. When the locomotive is travelling alone, however, a higher speed can be attained, and when being hauled a speed up to 30 km/h is quite admissible. The two axles, coupled together by rods, are driven by a standard nose-suspended motor through a double spur-wheel reduction gear giving a total reduction ratio of 1 to 11·3 (Fig. 2). Apart from the hand brake, the locomotive is equipped with a direct-acting compressed-air brake, which brakes on all

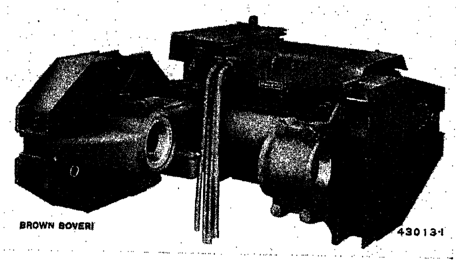

Fig. 2. — Driving motor with double reduction gear.

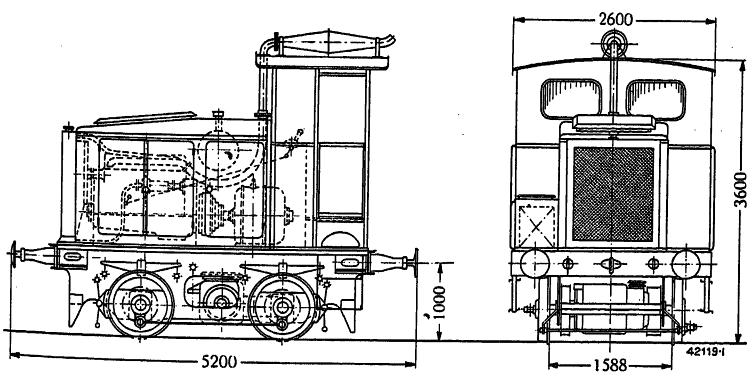

Fig. 1. — Diesel-electric shunting locomotive, 82/90 H. P.

four wheels through one shoe per wheel. The compressed air required for braking is delivered by a compressor which is belt-driven from the Diesel engine.

The Diesel engine is a six-cylinder, four-cycle unit by the Humboldt-Deutzmotoren A. G., Cologne, which develops 82 H. P. continuously and 90 H. P. for one hour at 1200 r. p. m. It drives a 51 kW generator through a flexible coupling and this generator supplies power to the D. C. traction motor of series type 45 kW at 210 V which is of the self-cooled design.

The control of the locomotive is very simple, the travelling speed being regulated, solely, by varying the speed of the Diesel engine, this by direct adjustment of the spring tension of the speed regulator. Handling is, therefore, very simple, indeed, and consists in only setting the sense of travel by means of the reversing switch and in adjusting the speed-regulating lever. The excitation of the generator is switched in when a change-over is made from no-load running to the first service speed, by means of a field switch actuated by the speed-regulating lever.

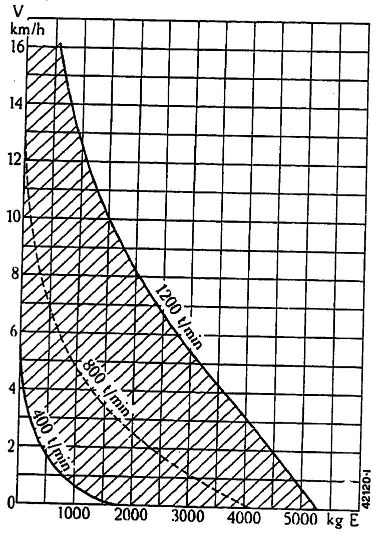

Fig. 3. — Tractive effort/speed curves.

E. Tractive effort at wheel tread.
V. Travelling speed.

The excitation current is not further regulated and is very low, so that it can be delivered by the starting battery or lighting dynamo. As under no load, the traction motor need not be separated from the generator, no other apparatus is required in the main and excitation circuits than the field switch, already mentioned, and the reversing switch. Fig. 3 shows the tractive effort-speed curve of the locomotive for the highest service speed (1200 r. p. m.) for the lowest (400 r. p. m.) and for an average speed (800 r. p. m.). As it is practically possible to set any speed between 400 and 1200 r. p. m., every setting of tractive effort and speed can be attained, between 400 and 1200 r. p. m., within the shaded area. This locomotive thus allows of an extremely gradual regulation of travelling speed, a very valuable quality in shunting service.

A 6-H. P. Scintilla starter is used to start the Diesel engine, the former being supplied from a 12-cell Tudor lead-plate battery. This battery has a capacity of 192 Ah with a 10-hours discharge and it also serves to supply the 24-V lighting equipment. The battery is charged by a Scintilla lighting dynamo of 1000 watts, built on to the Diesel engine and driven by belt. Charging takes place at all speeds between no-load speed and full load.

The equipment can be still further simplified if the lighting voltage can be chosen at will and if an alcaline battery, which is not damaged by strong and irregularly fluctuating charging currents, can be put in. In this case, the generator can be used to start the Diesel engine and, at no load, to charge the battery, so that both starter and lighting dynamo can be eliminated.

(MS 934) *Dr. E. Meyer. (Mo.)*

The Brown Boveri mutator plant of the Officine Elettriche Genovesi.

Decimal index 621. 316. 264 (45).

In 1933, a mutator set was delivered for the Officine Elettriche Genovesi, which was placed in the Via Canevari substation to supply power to the tramway system. The mutator set delivers 2300 kW at a D. C. voltage of 570 V corresponding to 4000 A. The overloads guaranteed are 50 % for two hours, 70 % for 15 minutes and 100 % for 1 minute. The high-voltage three-phase supply of the set is at 12,000 V, 50 cycles.

The mutator is of the well-known Brown Boveri B 712 type equipped with controlled grids for extinguishing short circuits. The vacuum-pump set is built on to the mutator. The control of the pumps is automatic and carried out with the help of a switching apparatus of the 12 b type, so that attendance in the plant is very simple and no constant supervision is necessary. The main transformer, Type TUW, is built for oil cooling by external circulation. The oil flows in a closed circuit, being cooled by cold water flowing in counter sense through a cooler. For the mutator, itself, indirect fresh-water cooling has to be used as the fresh water available is not suitable for direct cooling, owing to its corrosive character.

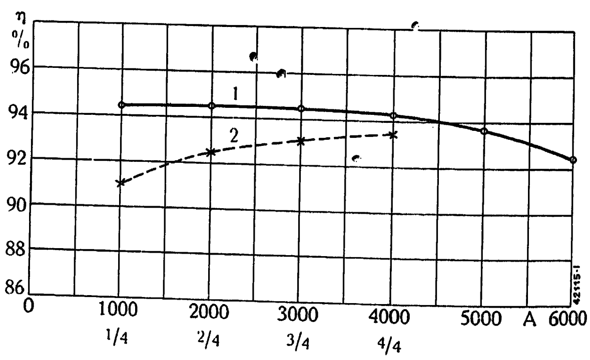

Fig. 1. — Efficiency of mutator plant in Carmine and Sampierdarena substations

Curve 1. Efficiencies measured.
Curve 2. Efficiencies guaranteed.

A quick-acting grid relay is employed for extinguishing short circuits. This relay is connected to two current tranformers inserted on the primary circuit of the mutator set. The requisite voltage for negative charging of the grids, to block the arc, is produced by a condenser connected up between the cathod and the grids (positive pole to the cathode) when the grid relay functions. The condenser is charged by means of a voltage-dividing resistance inserted between the + and the — poles of the mutator set. In standard service, the grids are connected up in groups to the secondary side of the excitation transformer, so that they are charged positively with regard to the cathode, in order to facilitate the ignition of the anodes, especially at low loads. Short-circuit extinguishing according to this principle has given good results and, further, has the advantage of eliminating rotating converter sets to produce the grid voltage.

Thanks to the good service results recorded with this mutator set, the same client ordered two others to be located in the Carmine and in the Sampierdarena substations; these new sets are already in service. These two mutators, 2300 kW, 570 V, which are of the B 712 type, have controlled grids and the same connections for extinguishing short circuits as were used on the first set described, namely with condensers. The mutator of the Carmine plant has a closed cooling system and artificial air draught, while that of the Sampierdarena plant has indirect fresh-water cooling.

Acceptance tests were carried out in the Carmine and Sampierdarena plants, at the beginning of May 1935, in order to determine the overall efficiency of the mutator sets. The efficiencies measured proved to be higher than the guarantees, as shown in Fig. 1. A full-load efficiency of 93,5 % was guaranteed and of 91 % at 1/4 load while an efficiency of 94% was actually measured between full-load and 1/4 load. The diagram shows that the efficiency remains constant between full load and 1/4 load which allows of very high yearly efficiencies being attained. This would not be the case if rotary converters were used as the efficiency of these machines drops sharply at low loads. The superiority of the mutators as compared to rotary converters is very evident in the present case. It is very advantageous, economically, to replace rotary converters by mutators; further, the latter have the advantages of requiring very little supervision, of making no noise, of low maintenance charges, of being able to handle heavy overloads and, finally, of taking up little room. Thus, in a given

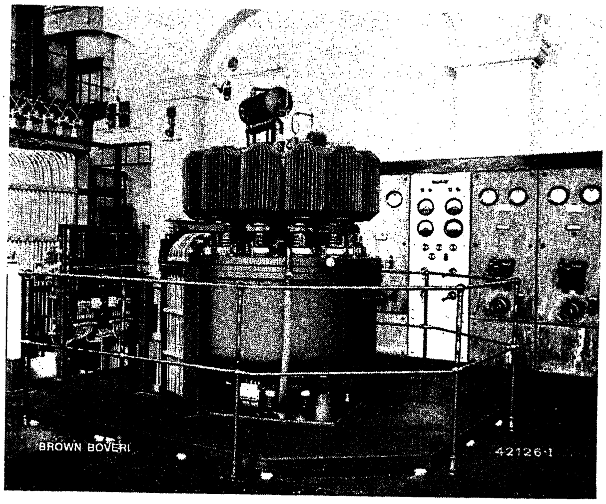

Fig. 2. — The Sampierdarena mutator plant of the Officine Elettriche Genovesi.

space the output of the mutator which can be put in is greater than that of the converter set.

(MS 953) *A. Greco. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2):621.313/4 (45).

THE Egidio e Pio Gavazzi weaving mill near Milan, writes to us that for an "unbelievable length of time" they have had Brown Boveri machines running in their Desio plant and that the same have given satisfaction during the long period they have been running. It will, certainly, interest our readers to learn when these machines were delivered. The main equipment is composed of:—

2 two-phase alternators Type WA 7/16 each of 250 H. P., 220 V, 40 cycles, 300 r. p. m. with separately-mounted exciters, factory numbers 1059 and 6096, delivered in the years 1895 and 1899 respectively.

1 two-phase alternator Type 2300/24 of 430 H. P., 220 V, 40 cycles, 200 r. p. m. with built-on exciter, factory number 6072, delivered in the year 1899.

4 single-phase transformers for lighting purposes, 220/120 V, 40 cycles, delivering together 80 kVA, delivered in the year 1895.

To these units must be added about

220 two-phase motors of 0·25 up to 0·50 H.P., 110 V, 40 cycles, 1200 r.p.m., delivered in the years 1896—1902.

Forty years of satisfactory service is, surely, an unassailable proof of quality and reliability in service of machines which, as it was expressed, have run "for an unbelievable length of time".

(MS 936) *Prop.*

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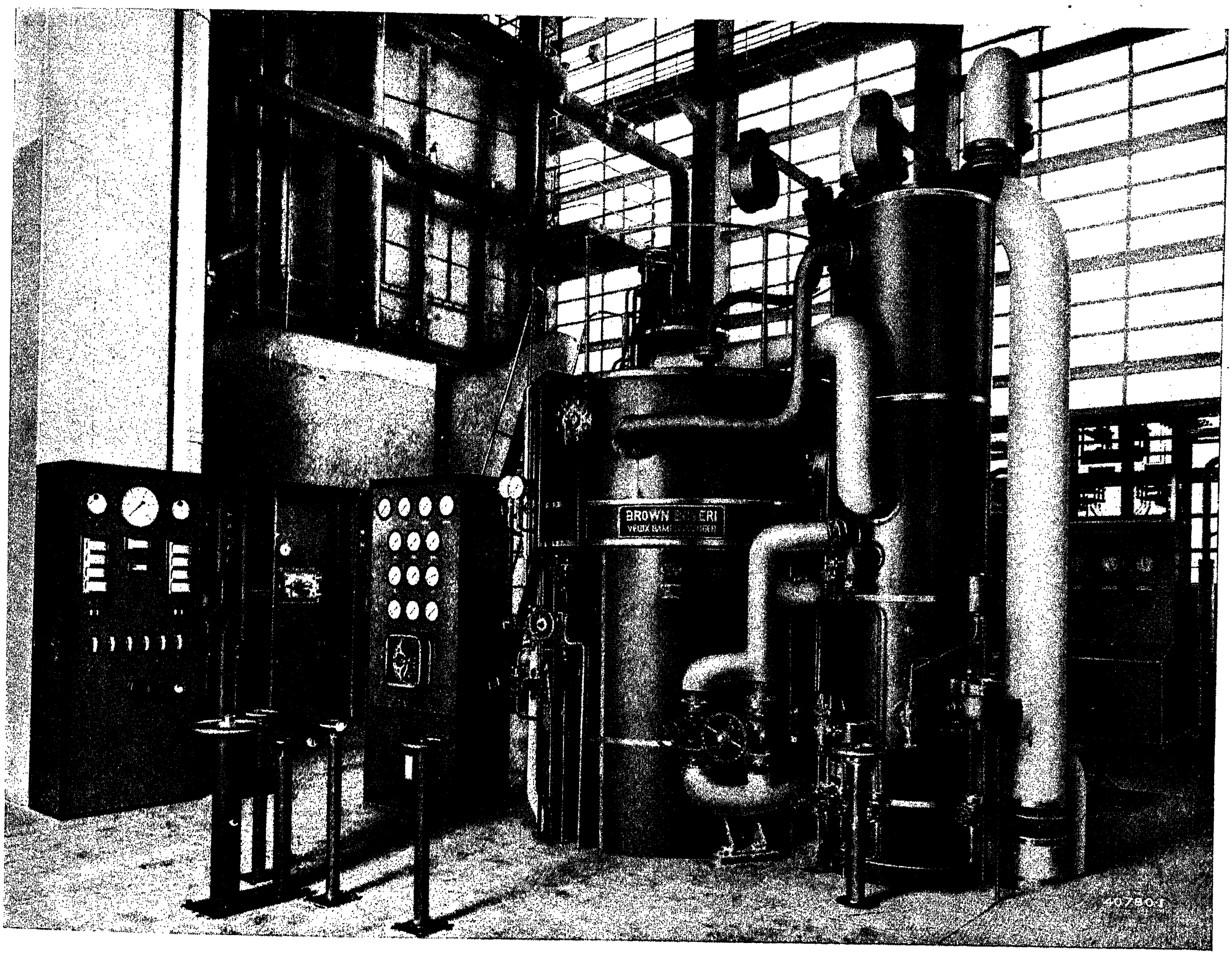
GENERAL INDEX TO VOL. XXII, JANUARY-DECEMBER, 1935.

FRONTISPIECES AND SEPARATE ILLUSTRATIONS.

VOL. XXIII JANUARY/FEBRUARY, 1936 (DOUBLE NUMBER) No. 1/2

THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



REMOTE CENTRAL HEATING AND POWER PLANT OF THE SWISS FEDERAL INSTITUTE OF TECHNOLOGY, ZURICH.
Velox steam generator, 18 t of steam per hour, 35 kg/cm² abs, 400° C, for fuel-oil firing.

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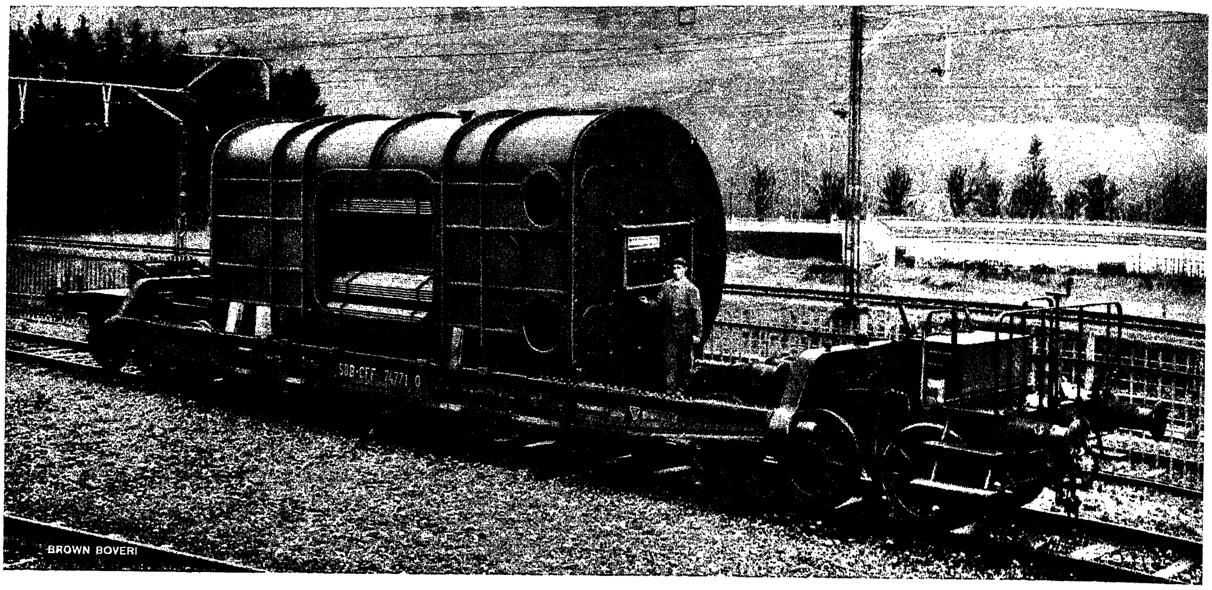
Printed in Switzerland



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THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIII JANUARY/FEBRUARY, 1936 No. 1/2

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PROGRESS IN BROWN BOVERI DESIGN DURING 1935.

Decimal index 621.3 (09).

INTRODUCTION.

OUR traditional January report on the progress made by Brown Boveri products in the preceding twelve months, has, heretofore, been characterized by a sharp division between electrical products and those of the steam-turbine department, with a subdivision of the former into machines, transformers, motors, apparatus, etc. This arrangement did not bring out the diversified *fields of application* of the products described — with the exception of some special lines such as marine and traction equipments; it made for a certain rigidity in the handling of the whole, which, if advantageous from the point of view of technical tabulation, did not make for facile perusal of the report.

We have, therefore, made a change, this year, and attempted a chronology which, if we may so express it, conforms to the flow of energy: i. e. we begin with steam generators, steam turbines and generators, pass on to power distributing plants and conclude with the application of our products as power consumers. Obviously, this leads to a certain amount of overlapping, but we think this will be tolerated. We trust the object pursued has been attained and that new readers of the Review will be added to our numerous older friends.

I. POWER PRODUCTION.

A. STEAM POWER STATIONS.

We have had 35 years practice in building steam turbines and condenser plants and 45 years practice in manufacturing generators, transformers, switchgear plants and the apparatus belonging thereto, but we have designed and delivered very few complete power stations, indeed. This was because that main unit of steam power station equipment, the boiler, was not included in our field of manufacture. Since our development of the Velox steam generator, however, which is a boiler in a very high state of development, and since it was proved that great savings in buildings, pipes and fittings could be made by designing the Velox and the turbine so as to form a compact unit, we have definitely taken up the designing and building of complete power stations in which we can incorporate the wide experience already possessed by us in the field of thermal and electrical machinery. In all cases in which the fuel available is oil or gas, we are now in a position to put forward extremely interesting proposal to our clients, for *Velox power stations* laid out so as to bring out the undoubted advantages of the Velox principle. Until the time comes when our investigations into the problem of coal-fired Velox steam generators have led to entirely successful results, we shall continue to work out designs for coal-fired steam stations, as well, using the most suitable types of ordinary steam boilers.

As first examples of Velox power stations built, mention must be made of the Haifa plant belonging to the Palestine Electric Corp., producing about 12,000 kW and of the Town of Oslo power station producing 32,000 kW, as well as of the Wellington power station, New Zealand, for 15,000 kW output.

Fig. 1 shows the Haifa Power Station. The Velox steam generator is in a machinery hall in which the Velox auxiliaries and the main steam turbines are also located. After the conclusion of the tests carried out by *Prof. Dr. Stodola* on the first Velox for the Haifa station, which tests were made in our Baden plant, and reported on here, last year, a second Velox was ordered and this second order was followed by a third one, for a third Velox, which order was given us after the successful trial tests carried out on site with the first Velox unit installed. The first Velox has now been operating for about 4000 service hours.

Fig. 2 is a plan view of the peak-load and stand-by power station of Oslo, situated in the central part of the town. The problem to be solved in this plant was to find room in the existing old boiler house

producing 15,000 kW (which it had been found necessary, to shorten considerably by stepping back a wall) for new boilers with 50 % stand-by capacity and a 32,000-kW turbo-set. This task was accomplished without difficulty by using Velox steam generators and even allowed of providing ample room for operating requirements. There are two Velox steam generators, each for 75 t/h of steam which is delivered to a Brown Boveri single-cylinder 32,000-kW turbine, placed close to them and coupled to a 35,000-kVA generator. The charging sets with charging blowers, gas turbines and auxiliary motors are located beside the Velox units in the machine hall. The condenser and the pump set of the condensing plant can be seen. The Velox and turbo-set are so laid out that a third Velox, as spare, can be put in, when necessary.

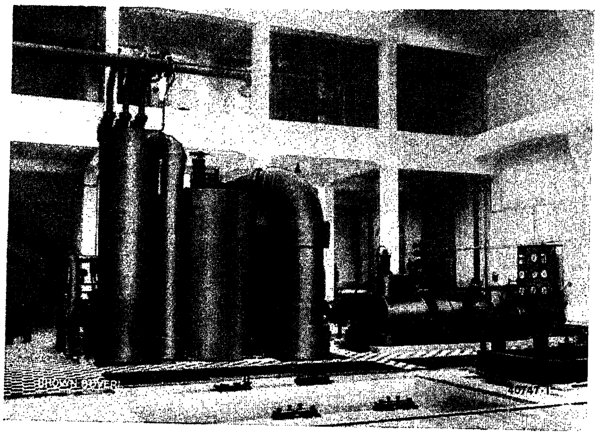


Fig. 1. — Haifa Steam Power Station of the Palestine Electric Corp. Velox steam generator for 34,500 kg/h of steam, 27 kg/cm² abs, 450° C with charging set composed of a gas turbine, charging blower and auxiliary motor. The steam generator and the steam turbines are located in the same hall.

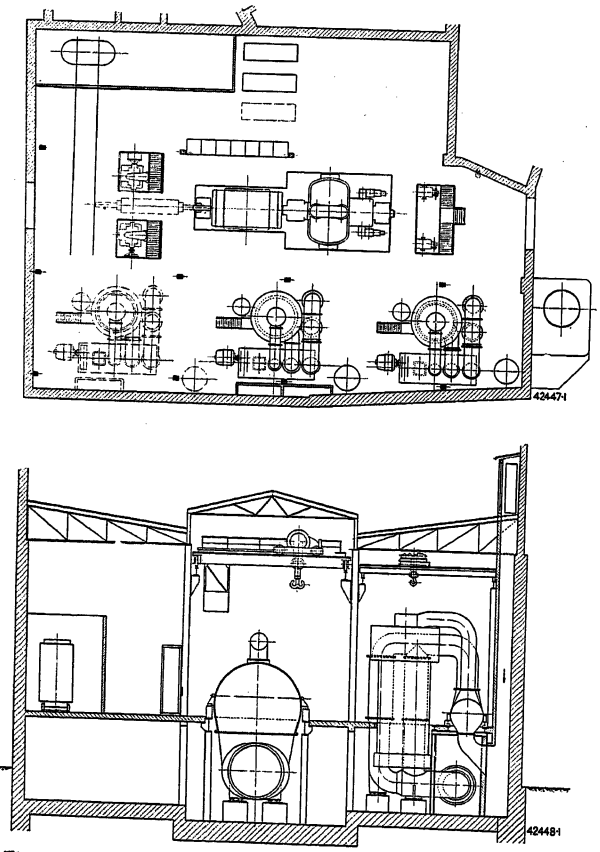


Fig. 2. — Plan of the peak-load and stand-by Steam Power Station, Oslo, Norway.
Two Velox steam generator producing together 150,000 kg/h of steam at 28 kg/cm² abs and 425° C as well as a Brown Boveri single-cylinder steam turbine for 32,000 kW with condensing plant. The whole power plant with spare steam generator was lodged in the space which formerly could only hold the boiler plant producing 15,000 kW; further, the building is even smaller now, a wall having been stepped back. The power station is in the middle of the town, built on to an hotel; it must, therefore, operate silently and produce no smoke.

Fig. 3 gives a plan view of the power station of Wellington (New Zealand) for 15,000 kW. There are two Velox steam generators here, delivering each 41 t/h of steam at 17 kg/cm² abs and 342° C, to supply steam to two 7500-kW Parsons turbines.

It was recognized, early, and confirmed by consequent developments, that the oil-fired Velox steam generator combined with the steam turbine form an excellent solution to the problem of the equipment of *peak-load power stations* and of *stand-by power stations*, this not only in plants where oil or gas fuel is cheap, but also in those which are coal-fired under ordinary operating conditions. The first of these Velox was that of Toulon (France) which takes over the station over-load peak every day and which was started up no less than 190 times in the course of last winter. The Oslo and

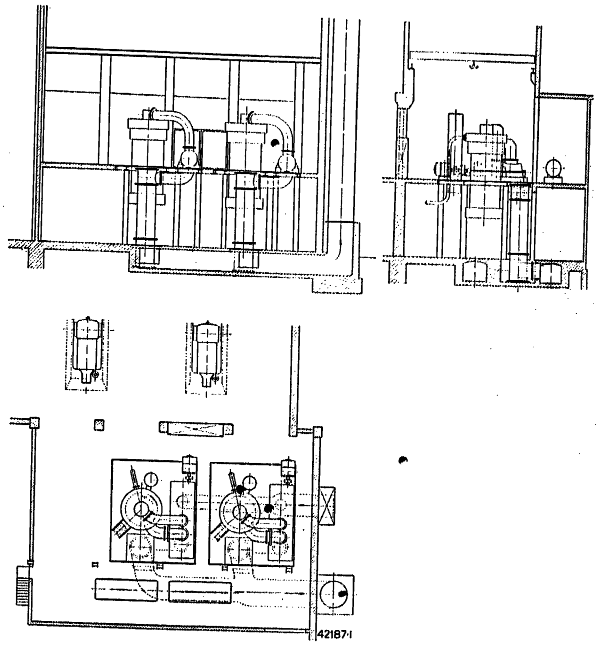


Fig. 3. — Plan of the Wellington Power Station, New Zealand. Composed of two Velox steam generators producing together 82,000 kg/h of steam at 17 kg/cm² abs and 342° C. to generate 15,000 kW. Here, as well, Velox and turbine units are located in the same hall.

the Wellington plants with the very latest, that of Caen (France), are other examples of this kind of station. Power stations thus equipped are always in a state of readiness for service and can be started up and put under load within a few minutes. They take up so little room that they can be placed on the very site where the power generated is to be used, if cooling water for the condenser is available there. The supplying of fuel to the plant is easy and clean and the combustion in the Velox produces no smoke, whatever the load may be, so there need be no hesitation in putting Velox plants in residential town quarters.

The locating of Velox steam generators and their turbines in the same hall, as is customary in plants of this kind, means considerable saving in building costs and economy in pipe lengths. We have studied a still greater concentration of Velox, turbine, condensing plant and generator with all accessory machines so that they form a machine-set entity which we have termed the *Velox motor*. This should prove an important factor in future steam plant developments. Of course, the Velox motor can only be used for plants, which require a turbine as well as a Velox and in those for which the turbine and the steam generator are ordered from the same manufacturer. The compact design of the Velox motor does not save space alone, but it also reduces length of piping, fittings and heat losses. By special sealing gland design, it is possible to make the Velox power plant

TABLE I.

Reference list of Velox plants (without naval plants).

Serial No.	Ordered by	Output in steam or in thermal units		Steam pressure or saturation pressure in kg/cm² abs	Temperature of steam or of hot water in °C	Fuel used
		kg/h	Mill of kcal/h			
1	Our own testing plant in turbine shop, Baden	10,000	—	34	400	Fuel oil
2	Our own plant for service and demonstration, Baden	18,000	—	35	425	Fuel oil
3	Blast-furnace plant in France	12,000	—	33	425	Blast furnace gas
4	Sugar mill in Spain	27,000	—	15 later 19	325	Fuel oil
5	A French electric power station	25,000	—	21	375	Fuel oil
6	Remote central heating plant in Spain	—	13·3	16	200	Fuel oil
7	Remote central heating plant in Switzerland	18,000	—	35	400	Fuel oil
8	Remote central heating plant in Switzerland	—	7·0	15	190	Gas oil
9	Remote central heating plant in Switzerland	—	7·0	15	190	Gas oil
10	Textile mill in France	16,000	—	25	375	Fuel oil
11	Electric power station in Palestine	34,500	—	27	450	Fuel oil
12	Chemical works in Spain	16,000	—	28	380	Fuel oil
13	Paper mill in France	12,000	—	29	400	Fuel oil
14	Chemical works in Rumania	18,000	—	36	400	Methane
15	Remote central heating plant in Italy	—	4·0	4	80—100	Fuel oil
16	Remote central heating plant in Italy	—	4·0	4	80—100	Fuel oil
17	Electric power station in Palestine	34,500	—	27	450	Fuel oil
18	Electric power station in Norway	75,000	—	28	425	Fuel oil
19	Electric power station in Norway	75,000	—	28	425	Fuel oil
20	Locomotive for French Railways	12,000	—	20	380	Fuel oil
21	Tobacco plant in France	4,500	—	16	dry sat.	Fuel oil
22	Machine works in Germany	4,000	—	56	450/475	Tar oil
23	Remote central heating plant in Spain	—	13·3	16	200	Fuel oil
24	French passenger steamer, 21,000 t	34,500	—	49	450	Fuel oil
25	Electric power station in Palestine	34,500	—	27	450	Fuel oil
26	Textile mill in Italy	8,000	—	27	400	Fuel oil
27	Electric power station in New Zealand	41,000	—	17	342	Fuel oil
28	Electric power station in New Zealand	41,000	—	17	342	Fuel oil
29	Electric power station in France	40,000	—	33	435	Fuel oil
30	Chemical works in Italy	40,000	—	40	440	Fuel oil
31	Chemical works in Italy	35–40,000	—	40	440	Fuel oil & gas
32	Oil refinery in U. S. A	23,000	—	29	505	Fuel oil & gas

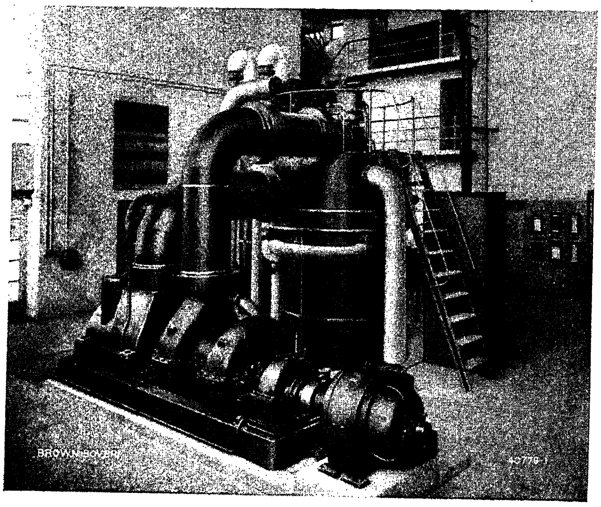


Fig. 4. — Velox steam generator for 18,000 kg/h of steam at 35 kg/cm² abs and 400° C in the remote heating and power station of the Swiss Federal Institute of Technology, Zurich.
The Velox is used as a spare and peak-load unit for a Sulzer-Garbe boiler of equal output and it also serves as an object for tuition, in the mechanical laboratory of the Institute.

as gas-tight as a refrigerating set and to use the same water in constant circulation, with a very small amount of make-up, indeed. Evaporating plants or chemical make-up water plants become very small and the problem of feed-water supply and boiler cleaning of secondary importance.

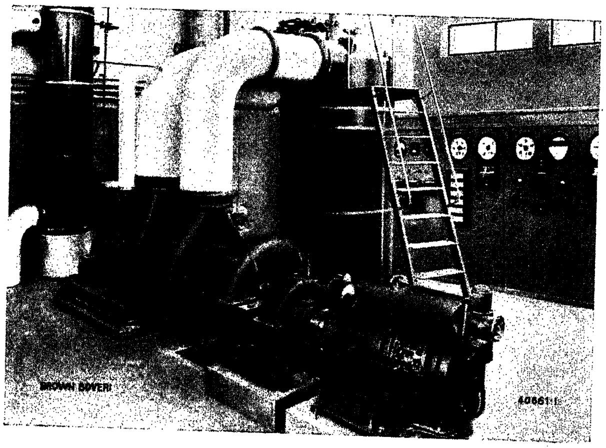


Fig. 5. — Velox hot-water generator of the Aarau Cantonal Hospital (Switzerland).
Built into a high-pressure hot-water Caliqua heating system. Each of the two Velox units is for 7 million kcal/h at 180° C. In the foreground, the charging set with a three-phase commutator motor as auxiliary. Starting up is performed by push-button control from the switchboard. Regulation is entirely automatic.

1. *The Velox steam generator.*

Without counting units for warships, there are 32 Velox built for a variety of uses which are either running or, on order, in our shops to-day. The accompanying table gives some data on these units:—

Apart from plants described already, Fig. 4 as well as the illustration on the cover show a Velox

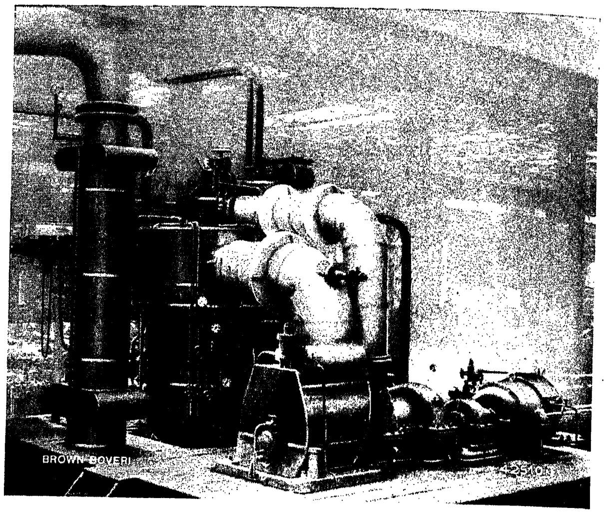


Fig. 6. — Velox steam generator for Messrs. Blin & Blin in Elbeuf (France), for 16 t of steam per hour; Velox on test bed of the Compagnie Electro-Mécanique, Paris.

steam generator delivered to the Swiss Federal Institute of Technology, Zurich, and used as a spare and peak-load unit for remote heating of the buildings and as a demonstration model in the mechanical laboratory. The illustration on the cover shows, on the left, a single-tube high-pressure boiler 100 kg/cm² delivering the same amount of steam and designed for oil and coal firing, built by Messrs. Sulzer Bros.

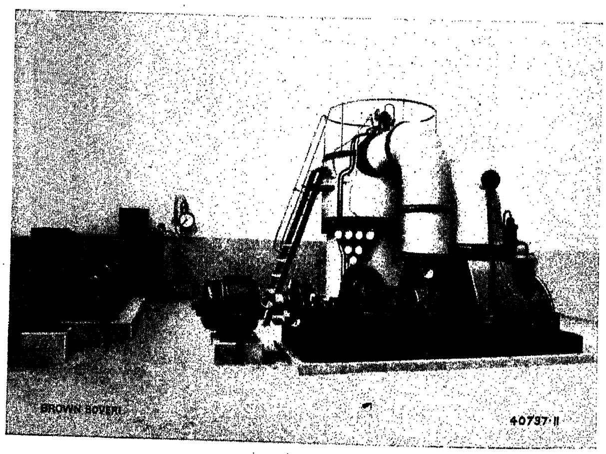


Fig. 7. — Velox hot-water generator of the Ciudad Universitaria, Madrid.
Built into a high-pressure hot-water Caliqua heating system; for 13·3 million kcal/h, 180° C.

The Velox is the ideal plant for *central heating stations,* which are required for populous town quarters, for hospitals, universities, etc. and for which it would be necessary to use oil fuel, in any case.

The Velox takes up very little room and its weight is only 10 to 20% that of an ordinary boiler plant. Foundations are proportionately light so that it is, even, feasible to lodge the Velox in an upper storey. This is a great advantage in town

areas and facilitates matters greatly for the architect and builder. The Velox plant as heat generator can be built as a hot-water Velox for hot-water heating purposes or as a steam Velox for steam-heating purposes. In the latter case, it will often be found advantageous to expand steam generated at high pressure in a steam turbine set, thus generating electric power, and then to use the steam at the lower pressure for the purposes of heating proper.

Fig. 5 shows a *Velox heat generator* for 7 million kcal/h for the heating system of the *Aarau Cantonal*

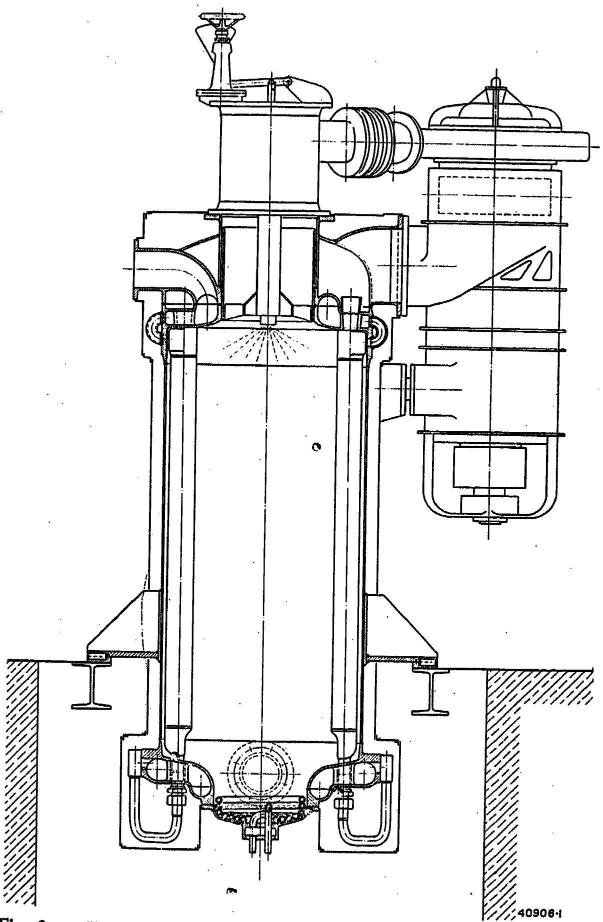


Fig. 8. — **Velox heat generator of the Città Universitaria, Rome.** The charging set is built on to the combustion chamber and piping is, practically, eliminated. Erection work is reduced to connecting up the Velox to outgoing pipes and to electric cables.

Hospital working on the high-pressure hot-water Caliqua system. The charging set is in the foreground with its three-phase commutator motor as auxiliary and starting motor. There is no superheater in a hot-water heating plant. Fig. 7 shows a similar plant for the Ciudad Universitaria, Madrid, for 13·3 million kcal; this is also a Caliqua hot-water high-pressure heating system. Fig. 8 gives a section of the new Velox heating plant built by Tecnomasio Italiano Brown Boveri for the Città Universitaria, Rome, for 4 million kcal/h. A very important improvement in small plants is incorporated in this Velox by building the charging set and the circulation pump straight on to the combustion chamber. The pipes for the set are mounted complete in the shops before dispatch. They are very short, have low resistance and little heat radiation. The foundation of the plant is very simple and the Velox and charging set can be put up quickly and at little expense.

Fig. 9a shows a drawing and Fig. 9b a view of a *high-pressure Velox steam generator.* It generates steam at 80 kg/cm² abs and delivers 5 t/h. The Velox design is fundamentally the same as that of other Velox units with some few differences of detail owing to its small size. Thus, for example, the evaporator elements are an integral part of the water chamber and are all dismantled together by the lifting out of the upper water header. The combustion chamber and all auxiliary machines and apparatus also form an integral whole, so that no erection work has to be done on site except to join up the Velox to the pipe lines leading outwards, carrying water, steam and fuel, and to connect it to the electric cables.

2. *Steam turbines.*

We have not many innovations to report on in this line of manufacture, which is one that has gradually been brought to a very high standard of perfection by decades of patient research and constructive work. Thus, for example, Brown Boveri reaction blading attains to-day efficiencies of 93÷95 % so that further improvement of steam-turbine efficiency cannot be very great, whatever innovations are introduced. The 3000-r.p.m. steam turbine, which is light, cheap and advantageous to operate, is built, to-day, up to outputs of 70,000 kW; it may be possible to go even higher in the output per unit if still greater improvements in materials are introduced. By making materials further impervious to the effects of heat, it may prove feasible to increase the steam temperature at the inlet and the efficiency of the steam-cycle process. The close conjunction of Velox steam generator and turbine opens up possibilities for using intermediate steam superheating and getting a better heat consumption of the plant.

Mention should be made, here, of two big *single-cylinder steam turbines* each of 32,000 kW, 3000 r.p.m., for the Oslo power station, already mentioned and for the Warsaw Electricity Works; these are, certainly, the biggest single-cylinder units at 3000 r.p.m. built up till to-day. The design is shown in Fig. 10, while Fig. 12 shows a low-pressure cylinder housing in the shops. The low-pressure blading is of double-ended design on account of the large volume of steam to be passed; the two low-pressure parts open opposite each other into a common exhaust housing. A single-

cylinder turbine like this one has, obviously, a somewhat lower efficiency at high pressures than a multi-cylinder unit. It is, however, very suitable to moderate and low pressures and is especially advantageous as a spare, as it takes up little space and is cheaper than a multi-cylinder unit; running as it does, then, for a short period of the year only, the question of high efficiency loses a great deal of its importance.

The generation of electricity in different industrial plants from the steam generated for heating purposes has made great progress, lately, as very cheap power

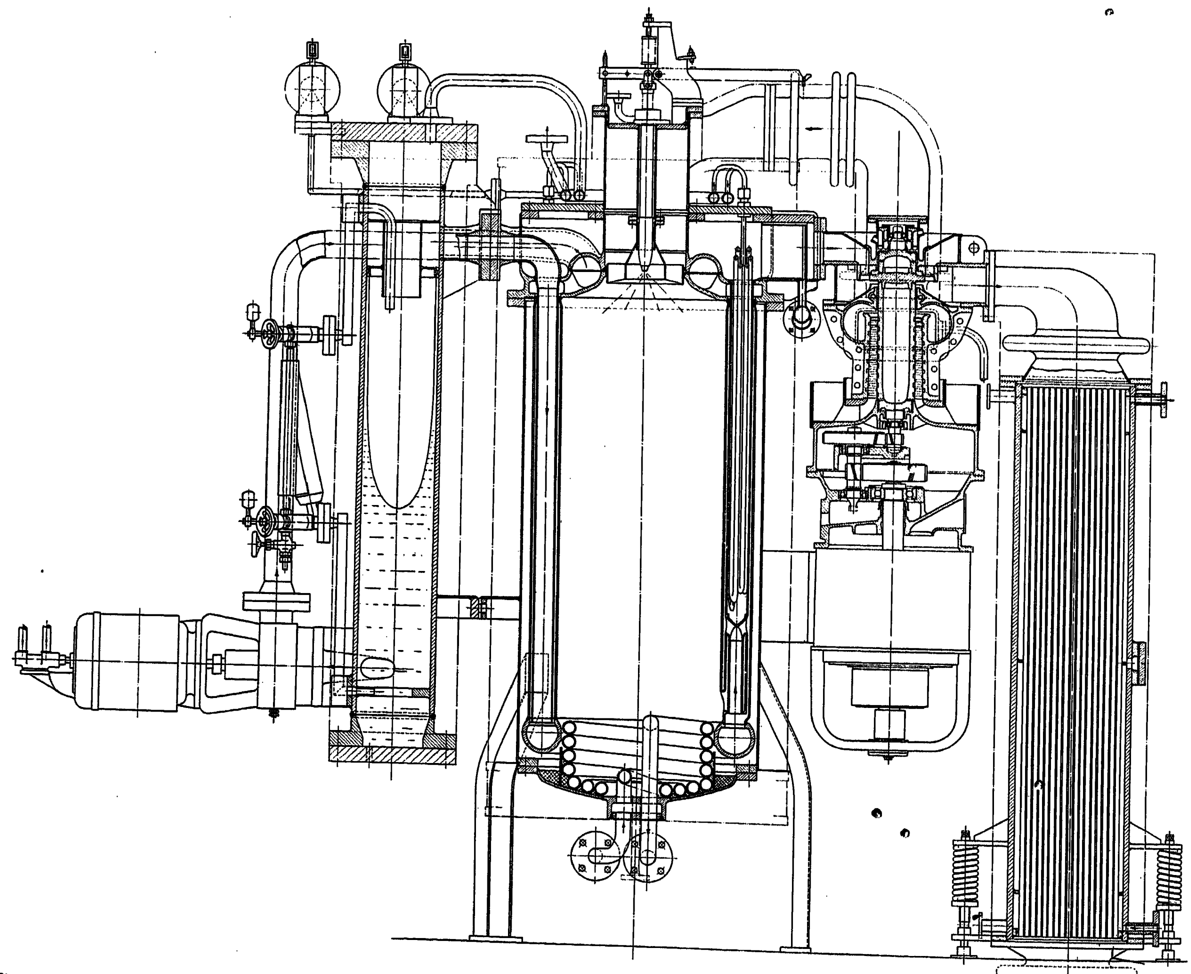


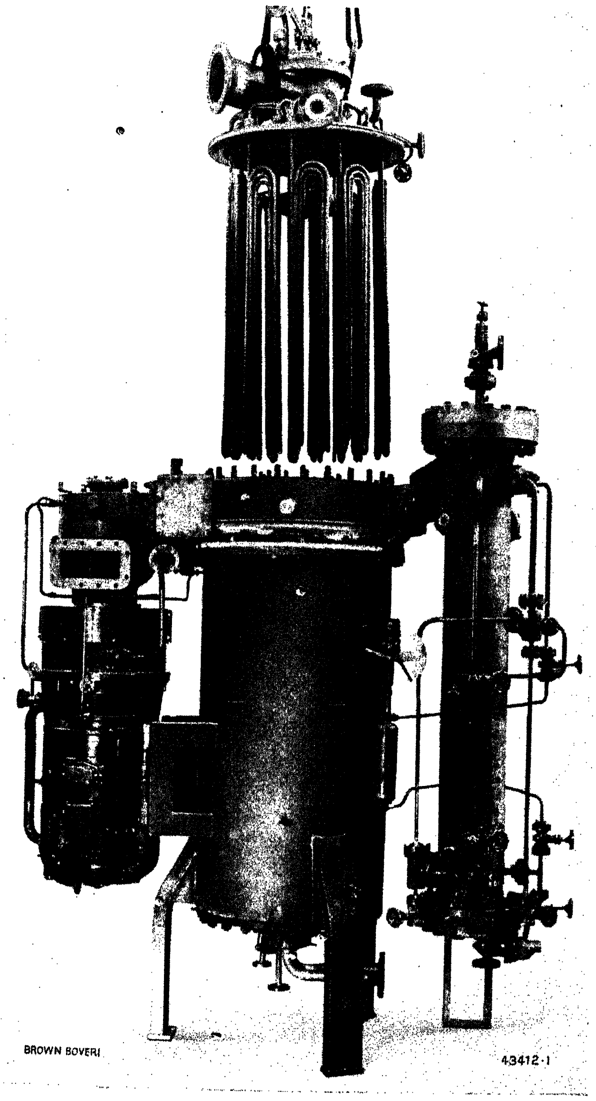
Fig. 9a. — Section of a high-pressure Velox steam generator 5000 kg/h of steam at 80 kg/cm² abs and 470° C
The charging set is built-on to the combustion chamber.

can be generated on this principle. Fig. 11 gives a section of a *steam turbine for an industrial plant,* such as finds many applications. It is a two-cylinder, double-extraction, condensing unit for 1500 kW, 460° C, 37 kg/cm² abs live-steam pressure, with extraction of steam at 9 kg/cm² abs, as well as at 4 kg/cm² abs. The high-pressure part consists of a Curtis wheel with two rows of blades and a reaction part, all in one housing. The medium-pressure part is similar in design and is located along with the low-pressure part in a common housing. Exceptionally, the low-pressure blading consists of two impulse wheels each with two rows of blades, this because the volume of steam to be passed is small; nozzle-regulation is used, as in the high and medium-pressure parts. The nozzle valves of the high and medium-pressure parts are governed by pressure regulators which maintain constant extraction pressures. The low-pressure part, in which is generated the amount of power still wanted and not to be got from the heating steam, is regulated by a centrifugal power governor.

We are pleased to be able to report on several improvements made on different *turbine organs* which have increased the reliability of our turbines still further. It has been found feasible to make a considerable increase in the specific load of our *thrust bearing* both as regards continuous and sudden loads by means of a new design and novel method of support of the carrying organs. Duration tests were made with bearing loads up to 500 kg/cm² at a peripheral speed of 50 m/s. In practice the

bearings only carry 1/20th of this load, so that there is a wide margin of safety even as regards exceptional stressing such as water hammer effects etc.

The *labyrinth glands* between shaft and turbine cylinder were made still tighter by reducing the size of the individual strips while increasing their number. At the same time, by fining down the elements form-



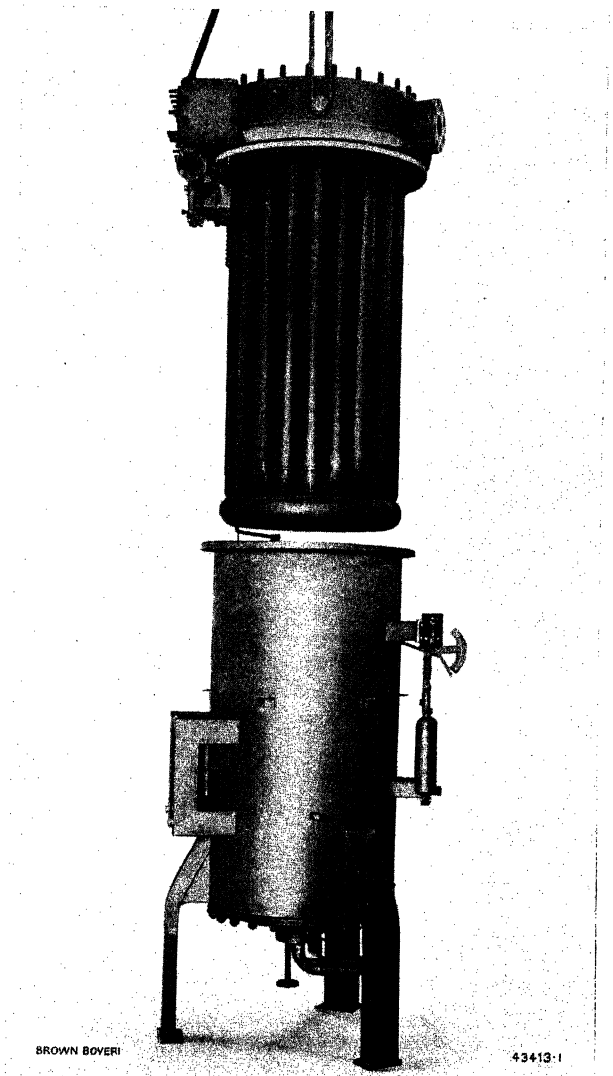


Fig. 9b and c. — High-pressure Velox steam generator, 5000 kg/h of steam at 80 kg/cm² abs and 470° C.
The whole plant with all auxiliaries and apparatus forms a compact set. It is easy to draw out the superheater. The evaporator tubes are welded to the upper water chamber and can be lifted out along with the latter.

ing the gland all danger which might arise from the strips coming into contact with the rotating parts, with consequent distortion of the shaft, is eliminated. We are no longer using carbon packing glands, as the great difference in expansion coefficient between carbon and steel did not make them suitable for turbines using high-temperature steam.

Such great improvements have been made in the *blading of the turbine,* as regards the blade profile itself, methods of securing the blades and connecting the latter, that blading trouble has been, practically, eliminated. Trouble due to the *erosion of blading* encountered in modern turbines can be said to have been, practically, overcome, to-day. We pointed out here, before, that this kind of blading wear was caused by water eliminated in the low-pressure stages. The amount of water and consequent danger of erosion increase the better the turbine efficiency, the higher the live-steam pressure, the better the vacuum and the greater the peripheral speed of rotor blading, all of which are qualities striven after in modern turbines. A poor turbine, generally shows no blading erosion and it is a quaint anomaly to hear a turbine vendor laud a turbine at the expense of one of another make on the grounds that the

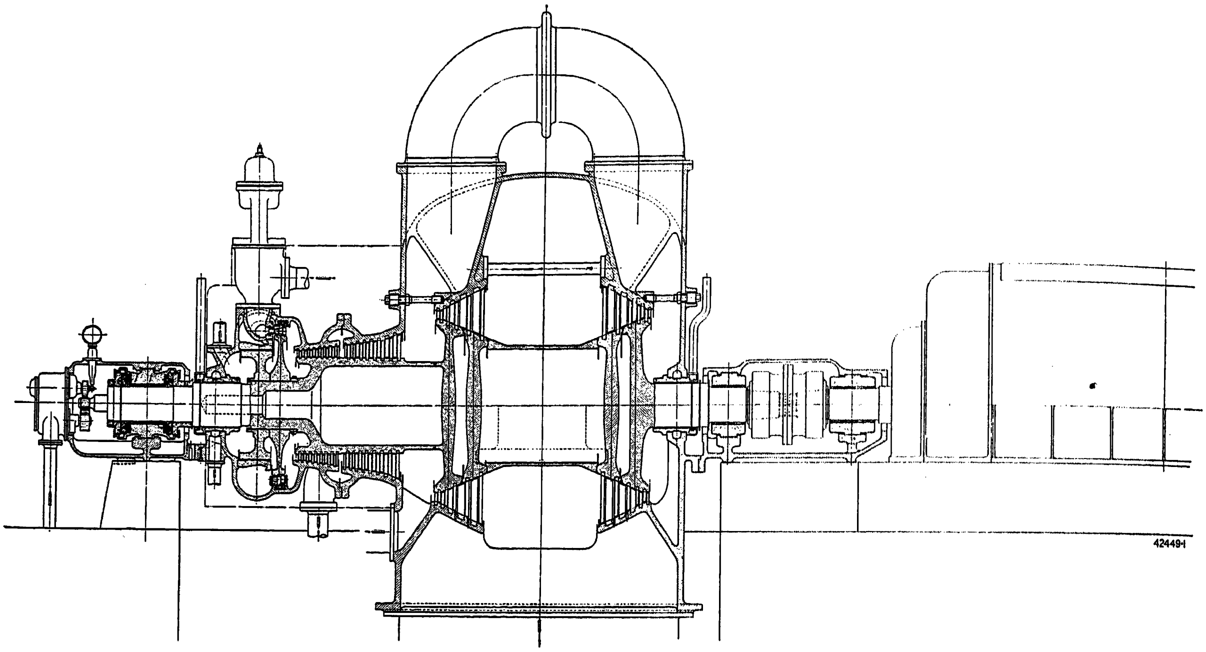


Fig. 10. — Section of a big double-ended single-cylinder steam turbine for outputs up to 35,000 kW at 40 kg/cm² abs and 450° C of the type used for the Oslo and Warsaw Power Stations.

The low-pressure part is double-ended with common exhaust housing, on account of the big volume of steam. The rotor is built up of separate parts welded together, according to a patented process.

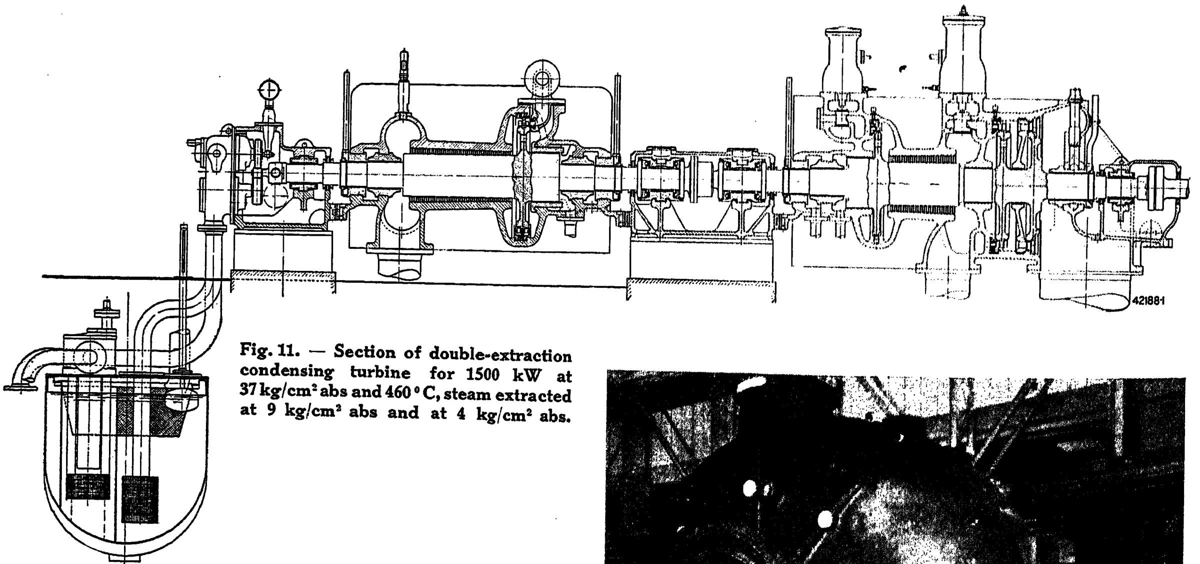


Fig. 11. — Section of double-extraction condensing turbine for 1500 kW at 37 kg/cm² abs and 460° C, steam extracted at 9 kg/cm² abs and at 4 kg/cm² abs.

blading has less to fear from erosion. Thus, for example, it has been affirmed that the velocities of the steam in impulse blading are greater than in the reaction blading, that the drops of water are better distributed and carried along and that their erosive effect is, thus, diminished. Theoretically, this is certainly true, but, in reality, the power of the steam to carry the drops of water along with it gets so low in the last rows of blades that the peripheral speed of the blades is practically the only factor governing the impinging of drops of water on the blades, and there is, practically, no difference at all

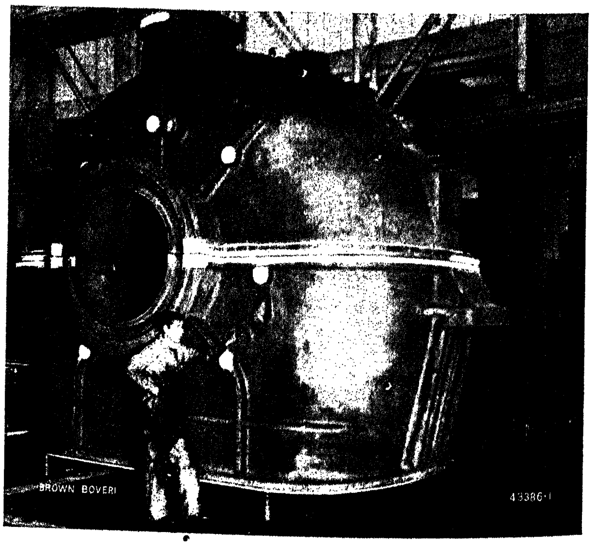


Fig. 12. — View of the low-pressure housing of a big single-cylinder steam turbine with double-ended low-pressure blading and a common exhaust housing.

between the two types of blading. Further, the last rows of impulse blades have a strongly-marked reaction character. It could be argued, contrariwise, that the reaction turbine is more impervious to water as the expansion of steam in the guide blade is only half accomplished and that, therefore, only half as much water does erosion work on the runner blade as in

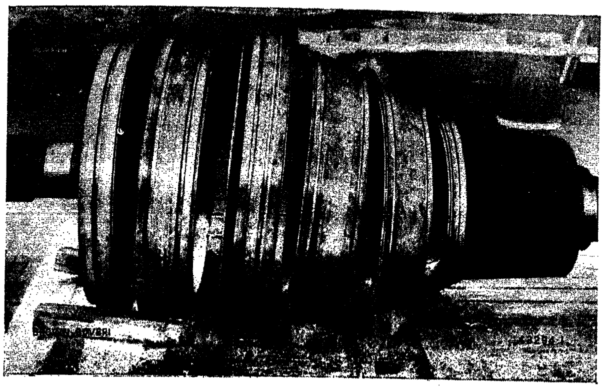


Fig. 13. — **Discs and shaft ends rough turned and ready to be welded together so as to form a steam-turbine rotor.**

an impulse turbine. In this discussion, it often happens that turbines which should never be compared, such as old slow-running impulse turbines, with poor efficiencies, are compared to modern fast-running reaction-type units with high efficiencies or else an impulse turbine with a few stages only is compared to a reaction one with many stages in order to prove that the impulse turbine is less subject to erosion than the other. We are sure of our attitude in this controversy on the different types of turbine, being well acquainted with *both* types of blades and having

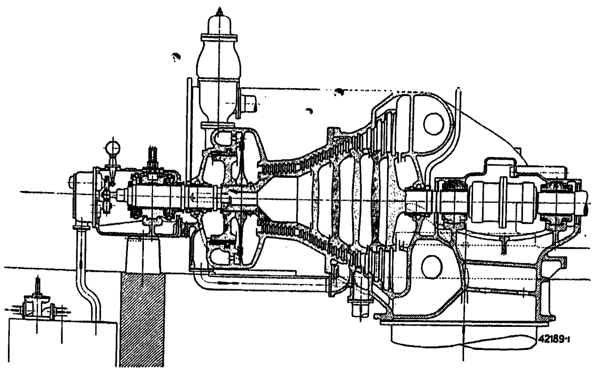


Fig. 14. — **Big single-cylinder steam turbine for 20,000 kW at 3000 r. p. m. with a rotor built up of discs welded together.**
Even at the highest temperatures, there can be no loosening of discs or loss of keys with this type of rotor (patent).

developed both to a high degree of perfection. We do not champion either system but use both, each one where it seems most useful to us for the purpose. Thus the high-pressure part of our turbines as well as complete small machines for small volumes of steam are built by us to the impulse principle while the medium and low-pressure bladings are of the reaction type, this being the combination which leads to the highest efficiency. As a result of this high efficiency, it is true that much water is eliminated but we have available constructive measures to make it innocuous. We have provided *draining*

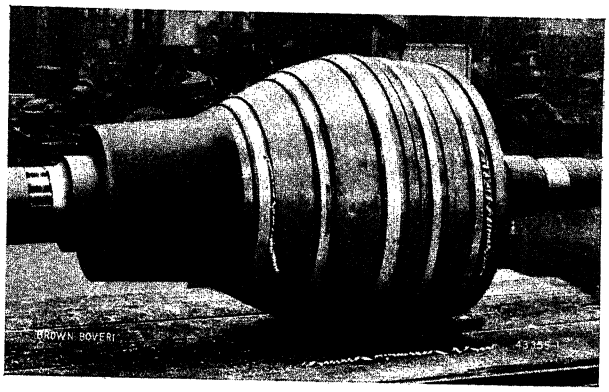


Fig. 15. — **The rotor welded after it has been turned up and before it has been annealed to get rid of all inner tensions.**

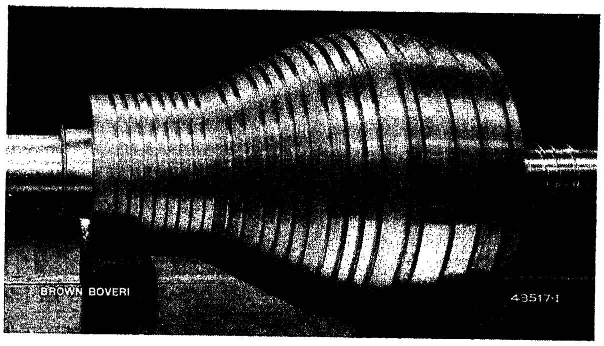


Fig. 16. — **Rotor turned up ready to be bladed and composed of discs welded together.**
No through shaft, no shrunk on wheels, no keys.

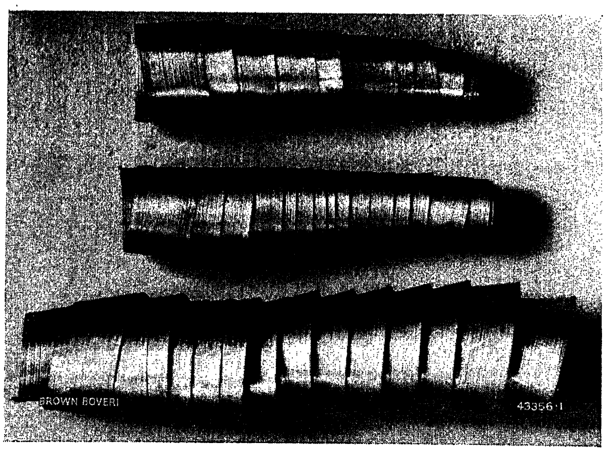


Fig. 17. — **Turnings taken from the welding proper of a welded rotor.**
The two upper turnings are composed of welding material proper. The lower one is composed, in half, of welded material. The turnings are perfectly homogeneous and of the same elasticity.

facilities so that as much water as possible is carried off from the blading at each stage. Further the blades of big units have *specially hardened surfaces* which is a Brown Boveri patented process, and are, thus, rendered, practically, immune from erosion. We reported here, earlier, on systematic comparative tests carried out on different blading material in the last row of blades of a 36,000-kW three-cylinder turbine, which was the biggest existing turbine working at 3000 r.p.m. at that time. These tests showed that the blades treated by the Brown Boveri hardening method showed hardly any signs of wear after 9100 hours of running and were far superior to all the other blades. A further report, after 13,000 hours running goes to confirm the great resistant properties of these hardened blades.

The Brown Boveri *steam-turbine and gas-turbine rotors*, built up of discs and separate parts *welded together*, have proved to be a *great advance in turbine design*, the proof being furnished by the service reports on about 130 units. Figs. 13 and 15 to 17 are typical examples of these rotors. This design allows of dividing the rotor into a number of full discs so that the separate elements have the most suitable shape and the lightest weight for withstanding the centrifugal forces and are, also, properly heat-treated through and through. The mechanical safety of welded rotors is complete because the stressing in the welding seams is only 50—100 kg/cm^2. There is no agglomeration of masses, the surfaces bathed in steam are big, so all parts quickly heat up when the turbine is started which prevents inner heat stressing in the mass. It often happens with massive rotor drums, that dangerous heat stresses are set up when starting is too rapid and these are all the more dangerous as the heat treatment is not always thorough in these types of rotor. With high live-steam temperatures and with the type of rotor in use, up till to-day, composed of separate discs shrunk on to a shaft, individually, big temperature differences between the different parts are unavoidable, at starting and stopping. It often happens, then, that a momentary loosening of the discs takes place when heating up is too rapid or an over stressing of the discs when cooling off is too sudden, as occurs if water gets into the turbine. This danger increased as the temperatures of live steam used were increased, in the space of a few years, by about 100^0 C, thus setting the designer difficult problems to solve. The new, patented, welded rotor in which the division of the parts and big heating surfaces prevent dangerous temperature differences, and with which loose discs on the shaft and keys thrown off are never met with, is a *very suitable rotor design for high temperatures;* it is a reliable design for rotors working at 500^0 C and more.

After these notes on welded rotors, which are the last word in high-grade welding, something should be said on the subject of *welding in general.* Our firm has been using welding for nearly 30 years and has turned out an enormous number of welded parts, in that time, while gaining much experience in the technique of the process. We have also built about 5000 welding machines and welding transformers and have frequently been able to give the purchaser valuable practical instruction on the welding process and impart to him the fruits of our very wide experience in the field. Since the year 1916, all the steam separators in the live-steam pipes of steam power stations have been delivered by us in welded construction and have shown themselves superior to all the difficulties offered by superheated steam, which used to be a source of trouble with rivetted steam separators. To-day, we weld pipes, flanges, condensers, preheaters, generator and motor housings, transformer tanks, compressed-air containers, bedplates, etc., in great numbers. The skill of our welding personel allows of making welded blower housings, gas-turbine cylinders and refrigerating plants. The Velox steam generator, as well, is a completely welded product and has no seams. The experience we possess and the reliability of our process assure absolutely reliable manufacture of the welded steam-turbine rotors, which were mentioned in the preceding paragraph.

We have been turning out welded pressure tanks during the last twenty years, both with the authority of the Swiss Boiler Society and with their approval and encouragement. As early as the year 1914, Mr. *Höhn* the chief engineer of the said society carried out tests and reached very valuable results. He recognized all the possibilities of the welding process and had the courage, at that time, to take responsibility for the application of the welding process to boiler construction. During the time the process was still little known, we met with no hindrance in exporting our welded products all over the world. Since, however, the boiler authorities in other countries have been obliged to reckon with the welding process, we have experience some quite ununderstandable opposition to the said process. As an example of this, we may mention a case where the boiler inspector of a certain country refused to accept welded flanges on a turbine exhaust pipe under medium pressure and temperature and insisted on having rolled flanges. In the International Standards on pipes and flanges which have been sanctioned by the Standard Committees of nearly all countries including the one in question, rolled flanges are completely barred on account of their unreliability under high pressures and high temperatures, while *welded flanges alone are accepted* for the highest stressing. It often happens that ignorance of new processes, the custom of using

and arbitrarily applying obsolete rules combined with hesitation to shoulder responsibility for innovations or, again, exagerated caution, hinder the industry of a country benifiting from the technical knowledge available. It is, obviously, a primary duty of inspecting authorities and experts to see to the safety of the material constructed under their supervision; but are they not under the further obligation to take full advantage of technical progress made which brings with it an *increase* in the reliability of the product and a reduction in cost? It would, indeed be wise to place confidence, in the studies made, experience gained and sense of responsibility of consciencious machine manufacturers, further, to ask for their advice before drawing up regulations and, thus, open the road to further developments by the said manufacturers, instead of binding them down too rigidly to narrow and unnecessary conditions.

3. *Condensing plants.*

In condenser design, the condenser type with tubes expanded into the tube plates and slightly bent, according to the Brown Boveri patent, has given an excellent account of itself. This bend imparted to the tubes prevents those dangerous tensions being set up in the latter which may arise due to the difference of temperatures between tubes and condenser shell. This design has eliminated *condenser leakages* and the dirtying of the condensate by cooling water. This design has allowed of a great saving being effected due to its *prevention of corrosion and rupture of the brass tubes.* As there are no sealing glands, it is not necessary to chose very hard tube material to prevent the tubes being squeezed in the glands; on the contrary, the expansion process allows of, and calls for, the use of soft brass tubes with which the danger of corrosion and ruptures is very much smaller. Up till to-day, Brown Boveri has delivered about 150 condensers with expanded and bent tubes and they have proved very successful. The illustration on the inside of the cover shows a complete condenser of this type, on a special car, intended for a 20,000-kW turbine.

In connection with the development of our small steam turbines, it has been found possible to improve the *pump sets of the condensing plants* both as regards space taken up and efficiency. Fig. 18 shows an auxiliary machine set for a combined drive, with motor and spare turbine, in which the cooling water pump, the condensate pump and the water-jet air ejector all form a block with the reduction gear for driving them. This design allows of imparting to the pumps as well as the driving machines the most advantageous speeds. Generally, drive is by electric motor and goes over automatically to drive by steam turbine (the turbine runs in vacuum under no load when not required) when the current fails. The steam

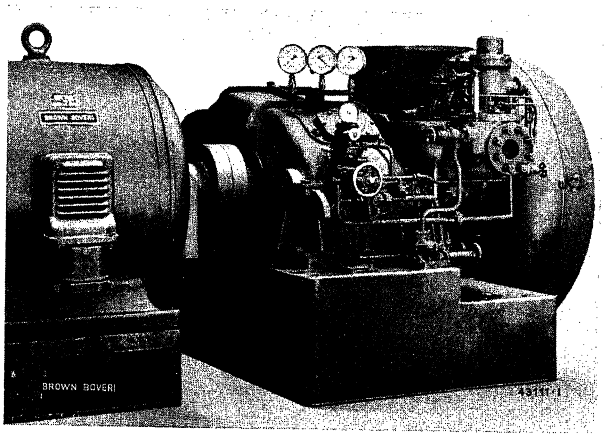


Fig. 18. — Pump set for the condensing plant of a 20,000 kW steam turbine.

Under usual conditions, drive is by electric motor and comprises drive of the cooling water pump, the condensate pump and the water-jet air ejector through a reduction gear. A spare steam turbine, which revolves in vacuum, under ordinary conditions, takes over drive of the set when the electric current fails. Gear drive of the several pumps, allows of driving each one at the speed most suitable to it.

turbine is governed by oil-regulated nozzles and gives enough power, even when the boiler pressure falls very much, to allow of the condenser-plant service being kept up in cases of trouble on the electric distribution system.

4. *Turbo-generators.*

The economic crisis put an end to the constantly-increasing kilowatt output of *turbo-generator units,* which characterized these machines in the years which followed the world war and did so for a period of about a decade and a half. When new units are called for, to-day, it will be noted that their output is nearly always below the maximum one attainable. This new development should not be a cause of regret in so far as two-pole machines go — and these are in the big majority — because the problems pertaining to mechanical strength which had to be solved in the case of rotors of turbo-generators between 50,000 and 100,000 kVA, had not been entirely investigated at the time the industrial crisis begun; considerable development work remained to be done before absolutely satisfactory conditions could be guaranteed.

The difficulties encountered are shown up clearly by a large-scale test carried out by us. Despite the considerable costs entailed, we did not hesitate to undertake this investigation in view of the importance to be attached to the results. A disc of 120 mm length was cut out of the middle of the cylinder of a single-piece rotor of 860 mm cylinder diameter and 1970 mm cylinder length, which had been built in 1923 and the tests records of which, taken on a test piece cut from the end of the cylinder according to the test methods

of that period showed quite satisfactory results, given in the following table.

Test piece	Yield point kg/mm²	Rupturing kg/mm²	Elongation %	Contraction %	Tenacity (notched-bar test) mkg/cm²
Tangential .	42·3	63·0	17·5	36	6·97
	42·3	63·0	12·5	19	6·48
Radial . .	45·0	63·8	(10·5)	44	11·2
	46·6	65·8	13·8	56	10·9
According to specification	35	60—70	16		6

The examination of the disc showed how prevalent fissures can be in a metal block, the outer layer of which is perfectly sound. The fissures revealed were up to 40 mm long and were unevenly distributed, being chiefly located in the middle between the bore and the outer surface (Fig. 19).

The deformation values such as elongation and contraction were uniformly low while the tensile strength values fluctuated considerably. It was clearly demonstrated that the heat treatment, in itself, of this piece of steel had not been insufficient but, nevertheless, it has to be scrapped on account of its many faulty spots. The differences between longitudinal and transversal test pieces were not very great, apart from the defective spots, and considerable differences only showed up in the elongation values. The influence of the heat-treatment slots only extended to the adjacent zone. The examination of the whole section by the Brinel hardness method revealed nothing whatever of all these faults; the hardness was exceptionally uniform. Analysis made on different radii also gave complete uniformity of alloy devoid of segregation of metals. The metallographical examination, however, showed clearly signs of the incomplete transformation of the primitive structure of the block, these signs becoming fainter from the inside towards the surface and taking the form of honey-comb shaped anomalies in perlite, of slag streaks degenerating into fissures and, finally, real flaky fissures (Figs. 21 to 24).

Fig. 19. — Section of a turbo-rotor in one piece of the year 1923.

In order to ascertain what stressing a rotor would stand up to, which has been proved to be defective, but would have been passed as sound according to the testing methods of that period, yet another disk was taken from the same rotor cylinder, to make an overspeed test on. The dimensions of this disc were such that the stressing was as similar as possible to that of a rotor with its winding complete running at 3000 r. p. m. This disc cracked at 6750 r. p. m. (Fig. 20). In the course of the different overspeed steps, the increase in the diameter was recorded over various measurement diameters and this allowed of calculating the behaviour of the specific radial expansions after making abstraction of the expansion due to heat. The interesting conclusion was reached that the local stressings in the rotor after the overspeed test left the piece in a state of internal tensions which manifested itself in compression stressing at the bore of the shaft and tensile stressing in the middle of the radius. It was also discovered that the tension peak at the bore caused very early local expansions; this shows that, practically, most rotors which are tested at overspeed are characterized, after the test, by an enlarged over-strained bore. This is not necessarily a drawback, because the internal tensions created thereby are opposed to the tensions arising in service and thus reduce the resultant tension peak on the bore.

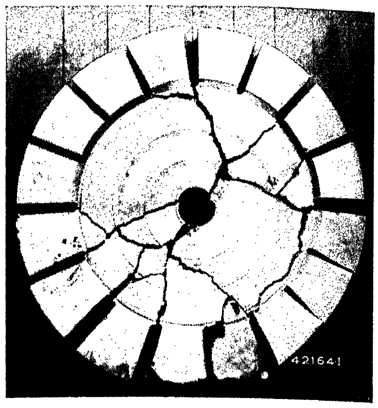


Fig. 20. — Test-disc, cut out of a turbo-rotor of the year 1923, which disc burst under an overspeed test, at 6750 r. p. m.

It is impossible to reconstruct the curve of the tensions from the remanent elongations measured, because there is no fixed relationship between the remanent elongations and the tensions which create them. It has been demonstrated in rupture tests that the remanent elongations are far greater under higher tension than in the case of the disc under overspeed test. This is due to the intervention of the phenomenon of automatic relaxation or adjustment tending to relieve over-stressed parts, a phenomenon accompanied by a strengthening of the material. This explains why the disc only broke under stressing amounting to 77 kg/mm² while its rupturing strength is only 63 kg/mm².

The taking of radial test pieces from different parts of the cylinder was, in itself, a considerable progress and, to-day, the examination of these pieces allows of determining with fair accuracy the quality

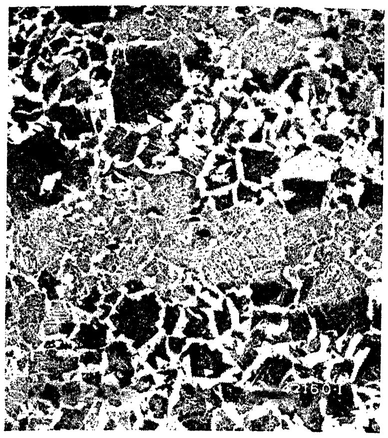


Fig. 21. ×54

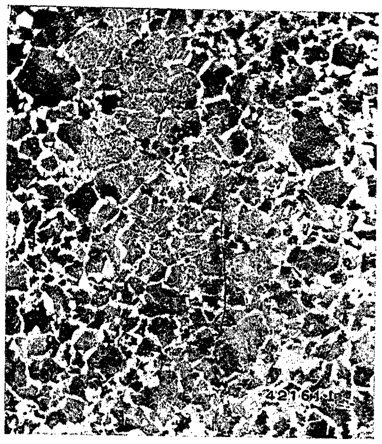


Fig. 22. ×54

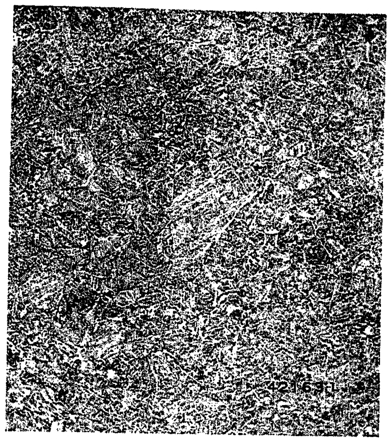


Fig. 23. ×54

Figs. 21—24. — Microphotographs of the structure of a turbo-rotor in one piece, of the year 1923.

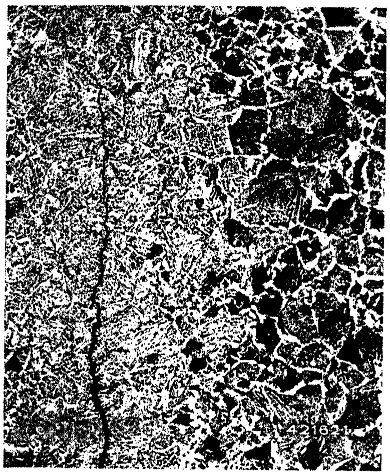


Fig. 24. ×54

of the whole. The determination, however, is not absolute and uncertainty grows with the size of the forging. But, the bigger the piece the greater the difficulties of perfect forging, which becomes a matter of impossibility beyond certain dimensions of the piece. The unavoidable uncertainties and the technical difficulties encountered in forging the rotors led us to seek another solution of the problem, namely a rotor design in several parts, to be used, from time to time, for special conditions. Fig. 25 shows a rotor of this type. The rotor body proper is carried by a long bolt provided with threads at both ends. This bolt is treated so as to have an exactly determined internal preliminary tension so that the pressure on the separation surfaces of the rotor parts is a multiple of the bending stress. A rotor of this type, as shown in Fig. 26, behaves dynamically like a rotor in one piece and has the additional advantage of being built up of plates, discs or short tubes which can be perfectly forged throughout and the use of which is an undoubted guarantee of reliability.

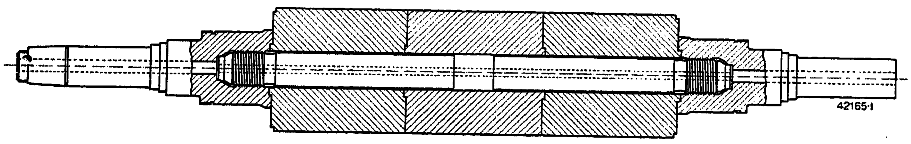


Fig. 25. — Brown Boveri design of a turbo-rotor in several parts.

Important and interesting progress was recorded in the field of *insulation of turbo-rotor windings.* The insulation of these windings, while having as thin walls as possible, must possess first-class properties of mechanical rigidity and good heat-transmitting qualities. These two conditions are difficult to conciliate; measurements carried out, on machines which have been some time in service have shown an increase in the heating of the rotor winding, while turbo-rotor windings of identical type often heat up differently, even when new.

The cause of these discrepancies was shown to be the relative unreliability of the mica preparation used for insulating purposes. On the one hand, the mica with its unlimited property of fissuring was not able to meet the fluctuating stresses put on it and, as time went on, loosened the firm seating of the coils. To this must be added the property of shellac used as a binder either to soften under heat, if insufficiently bound, and then to act as a lubricant or else, if over-dry, to loose its power as a binder and to pulverize. This allows air to penetrate which, although not dangerous, here, from a dielectric point of view, has a very deleterious effect on the transmission of heat from the winding

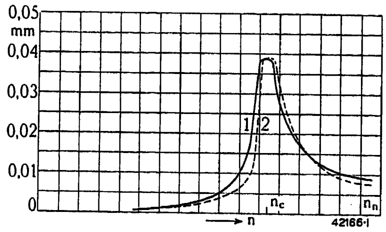


Fig. 26. — Oscillation amplitudes in function of speed.

1. Built-up rotor. n_c. Critical speed.
2. Massive rotor. n_n. Rated speed.

to the iron. For these reasons we have developed a new preparation to insulate turbo-rotor coils. The tests and first practical experiments date back some years. At first, owing to the very high cost of production, it was only possible to use the process in a few cases. However, the manufacturing methods have been so far developed, now, that we have been able to make general use of the process.

The new insulating material is much superior mechanically and thermally to the earlier one; it dœs not age practically at all and is impervious to dirt and damp. When combined with the new building-in process of the coils, it produces a compact firmly-seated winding, subject to no transformations in service. The heat transmission from copper to iron is considerably improved as is shown by a comparison of the heating curves when the old and the new insulations are used (Fig. 27). Owing to the reduction of the temperature difference between copper and iron, the relative heat elongation is brought down so that difficulties due to heat elongation are no longer experienced even with the longest length of slots encountered, when the coil heads are carried out according to our standard practice. Fig. 28 gives a section through a turbo-rotor coil insulated according to the new method.

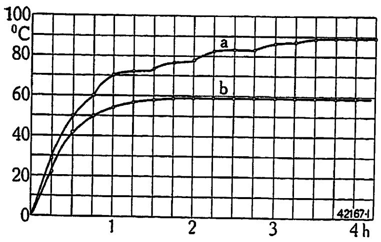


Fig. 27. — Temperature rises of rotor winding of a turbo-generator under equal excitation.

a. With the old slot insulation.
b. With the new slot insulation.

As regards *turbo-generator housings,* welded rolled-plate construction has, practically, become the general rule. These lighter designs are more adaptable, firstly, as regards the passage of cooling air and, secondly, for the putting together of the machine. Based on the experience gained in making stator coils for a 36-kV generator, the insulation of stator windings has been considerably improved and perfected. Stranded bars, along with the coil-head connection comprising the *entire* pole pitch, are made in one piece, which leads to a simple form of winding, easy to follow.

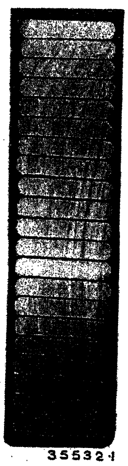


Fig. 28. — Section of a turbo-rotor coil, insulated according to the new process.

Among interesting turbo-generators built by the Brown Boveri concern within the past twelve months, mention can be made of the following:— two sets each of 31,250 kVA, 3000 r.p.m., 5250 V, 50 cycles connected to radial turbines. The stator and rotor designs are fundamentally the same as for units to be connected to axial turbines, i.e. radial ventilation in stator and radial slots in the rotor to take the excitation winding, a design which, all in all, is considerably more advantageous and reliable in service than that with parallel slots. Further, two units each of 4700 kVA, 3000 r.p.m. to be driven by radial-type turbines, as well, which generators are characterized by the relatively high voltage of 15,750 V, when the low output is considered. Two high-frequency turbo-generators were also built for artificial silk mills, for 1875 kVA, 4650 r.p.m., 155 cycles and 1430 kVA, 4800 r. p. m., 160 cycles. The popularity of two-pole turbo-generators of low power is worth noting. A unit of this type was built for the Electricity Works of the Town of Belgrad to deliver 1250 kVA; it weighs only 4 t in all. A promising field for this type of machine is found in sugar mills. Despite the industrial crisis, our concern built an aggregate of nearly half a million kVA of turbo-generators in the course of the last year.

B. DIESEL POWER STATIONS.

The generation of power by Diesel engines in power plants on board ships and on vehicles received a great impetus from the practical application of the *Büchi charging process by means of Brown Boveri exhaust-gas turbines and charging blowers.*

The curve of Fig. 29 shows the rapid development of this process in recent years. Over 30 Diesel-engine manufacturers have adopted the charging process with exhaust-gas turbine and many very important ones, such as MAN, Harland & Wolff, Deutz, Tosi, have concluded licence agreements with the Büchi Syndicate. The improvement of the efficiency of even the small charging sets which we have succeeded in attaining, quite recently, allows of the charging of road-truck Diesel engines of 100 H. P. so that they deliver 160 H.P. Here, the charging blower only weighs 25 kg is 280 mm in diameter and 350 mm long. The additional power gained of 60 H. P. is, thus, reached by the very small addition in weight of 0·42 kg/H. P., a very important factor for Diesels used on vehicles. Fig. 30 shows a standard MAN Diesel engine, 920 H. P. the output of which is raised to 1400 H. P. by charging. Fig. 31 shows a two-shaft Diesel engine in V design, in which the charging blower is lodged between the two rows of cylinders. Both arrangements show how simply and compactly the exhaust-gas turbo-blower can be combined with the Diesel engine. The turbo-blower of Fig. 30 projecting above the Diesel engine, is located above the driven machine and, like that of Fig. 31, does not take up additional space. Fig. 32 shows a

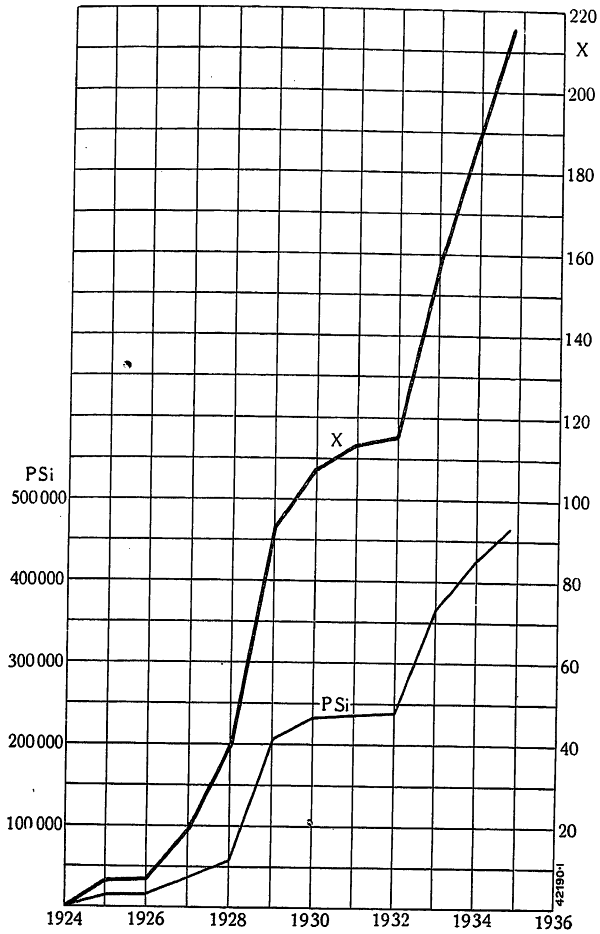


Fig. 29. — Development of the charging process on four-cycle Diesel engines, according to the Büchi system, with Brown-Boveri charging blowers and exhaust gas turbine.

More than 30 Diesel engine manufacturers use the charging process.
x. Number of units.
PSi. Total output of charged Diesel engines.

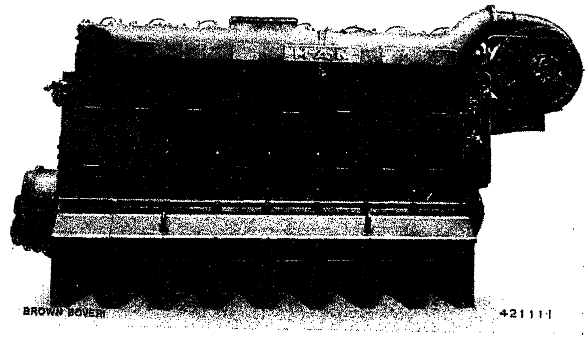


Fig. 30. — MAN Diesel engine of 920 H. P. at 700 r. p. m. Charging by exhaust-gas turbo-blower brings the output up to 1400 H. P. The charging blower is placed on one side over the machine driven.

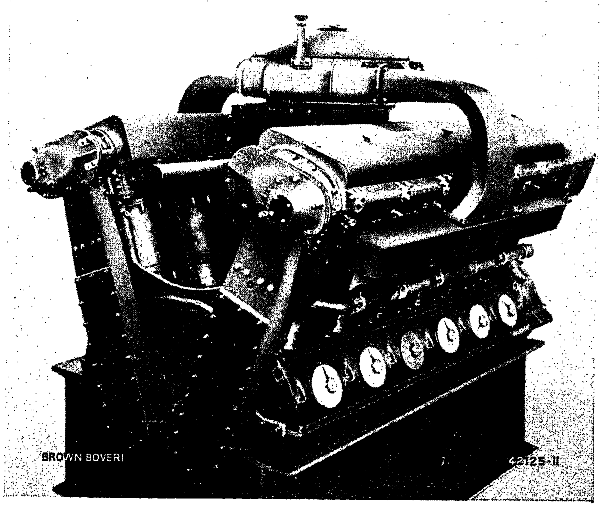


Fig. 31. — High-speed MAN Diesel engine for a motor coach for 420 H. P. with two shafts. Charging by exhaust-gas turbo-blower brings the output up to 600 H. P.

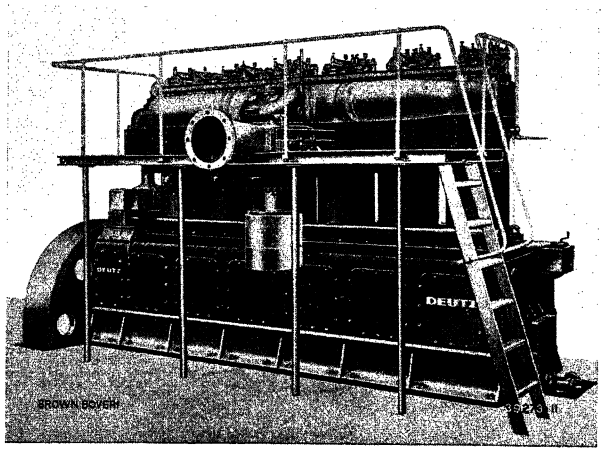
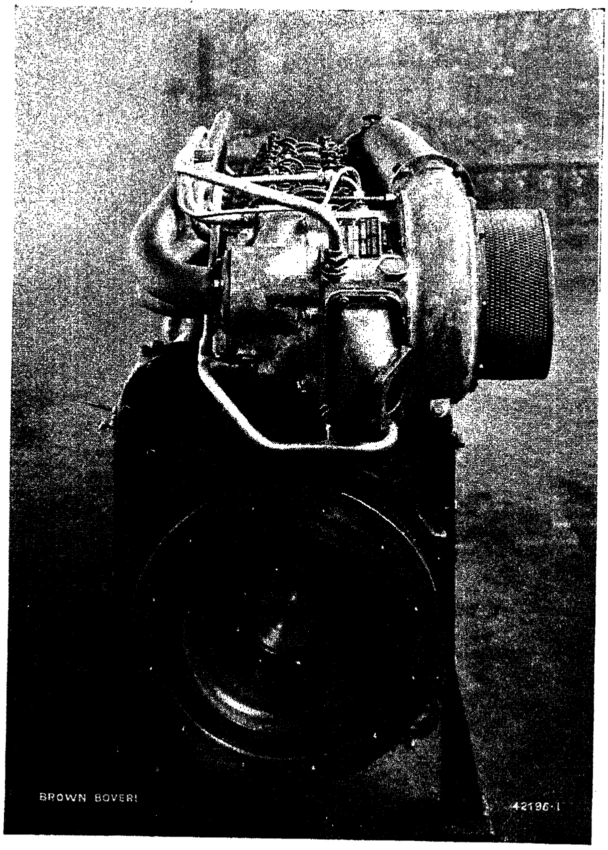


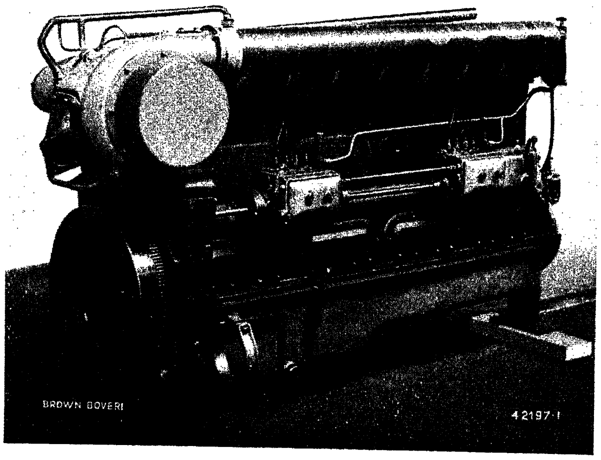
Fig. 32. — Stationary Deutz six-cylinder Diesel engine of 750 H. P. Charging by exhaust-gas turbo-blower brings the output up to 1100 H.P.

Deutz Diesel engine of 750/1100 H.P. and the little space required by the charging set is clearly seen. The constructive combination of motor and charging set is particularly striking in the case of the Deutz Diesel engine shown in Figs. 33a and b. This is an 8-cylinder motor-coach engine, by Deutz, for 1500 r. p. m. which delivers 210 H. P. instead of 130 H.P., thanks to charging.

C. HYDRAULIC POWER STATIONS.

Actual industrial conditions have caused a slowing down in the development of water wheel-driven generators, just as was the case for turbo-generators and this extends, to a certain degree to transformers of the largest outputs. It, therefore, seems fitting, to give a backward glance at the constructional progress made, in recent years, in the design of these machines. It is especially satisfactory to us to have, in close proximity to Baden, impressive testimony to what we have accomplished, as regards the field of low-head hydraulic plants, namely in the Rhine and Aare Power Stations of Ryburg-Schwörstadt, Albbruck-Dogern and Klingnau. Our firm delivered all the generators and a large number





Figs. 33 a and 33 b. — Deutz eight-cylinder motor-coach Diesel engine, 1500 r.p.m., of 130 H.P. Charging by exhaust-gas turbo-blower brings the output up to 210 H.P.

The engine and charging set are so built together as to form an organic whole.

of the transformers to these plants, besides a considerable quantity of switchgear.

The Ryburg-Schwörstadt Power Station (Fig. 36) with its four enormous generators of each 32,500 kVA at 75 r.p.m., 50 cycles, 10,500 V (Fig. 35) makes use of an 11·9 m fall on the course of the Rhine and has a total capacity of 1000 m^3/s of water. In ordinary years, the station, if fully utilized, can produce 600 million kWh per year.

The Albbruck-Dogern Power Station has three generators (Fig. 37) of quite the same design as the above. It uses a fall on the course of the Rhine of 10 m and takes 900 m^3/s of water. Its average yearly production amounts to 470 million kWh.

The Klingnau Power Station belonging to the Aare Werke Co. (Fig. 38) utilizes a fall on the River Aare of 5 to 7·6 m and takes a volume of water of 660 m^3/s. This station contains three generators of each 19,500 kVA at 75 r.p.m., 10,500 V, 50 cycles (Fig. 39). It is designed for a yearly output of 230 million kWh and delivers power, at present, to the long overland 220-kV transmission line which starts from the Bürs Substation near Bludenz belonging to the high-head hydraulic station Parthenen in the Montafon Valley (Vorarlberg) and ends in Brauweiler, near Cologne.

Fig. 34 shows the Chandoline Power Station of the Dixence Co. which was started up last year and is worthy of mention. *Prof. Dr. Landry* of Lausanne, the designer of the Dixence station, has accomplished his task in a manner deserving of general admiration. The whole plant is a masterpiece of simplicity conceived with the object of allowing easy supervision of the whole. This station works under the highest head of water of any existing power plant, namely 1750 m. We delivered the complete switchgear equipment (mention of which is made, further on) of this most modern of power stations.

1. *Generators.*

Generators are an element in hydro-electric power station equipment which have shown a remarkable development. We have described here, on former occasions, the biggest and most interesting generators built by us and our concessionary companies and given sectional drawings thereof. To-day, we can summarize as follows:—

The pole wheels of generators to be coupled to vertical-shaft low-head turbines at low speeds are, naturally, of the spoke type. When the diameter grows beyond a certain limit, these wheels are built up of several parts and, in certain extreme cases, it is found necessary to make the rim out of segments bolted to the wheel spokes, the poles being usually bolted, in their turn, to this rim. For generators to be coupled to the propeller type of water turbine, the speed of which, when the set is suddenly unloaded (run-away speed), goes up to more than twices and up to 2·5 times the rated speed, the poles are dovetailed into the rim of the wheel, one or two dovetails being used per pole.

Among the biggest and most important machines for low-head power stations, built in the last decade,

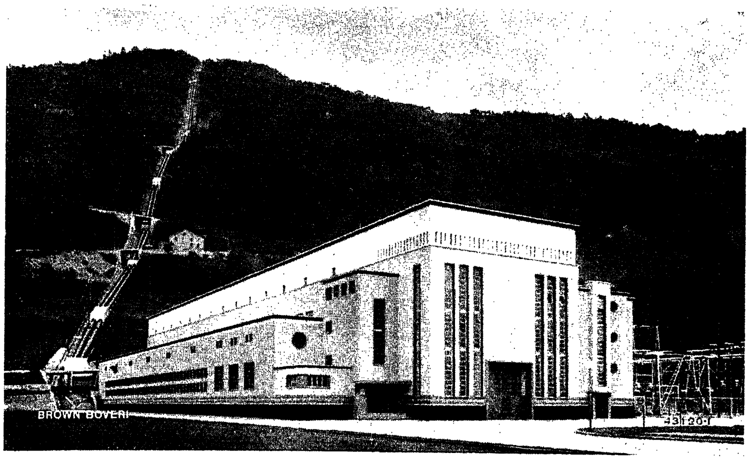


Fig. 34. — Chandoline Power Station of the La Dixence Co.
Main building of the station.

we would recall the Ryburg-Schwörstadt generators and those of Albbruck-Dogern which have two pole wheels each, located one above the other, while the units for the Klingnau station of the Aare Werke Co. have single pole wheels, as they are of lower output. In generators for higher rated speeds, to be coupled to high-head turbines and having relatively small diameters, the pole wheel is built up of S.M. steel discs, the number of which depends on the width of the machine. In one particular case, the conditions to be met, i.e. high-peripheral speed and big dimensions, led to a cylindrical rotor design with the excitation winding lodged in slots as in turbo-generators (Fig. 40).

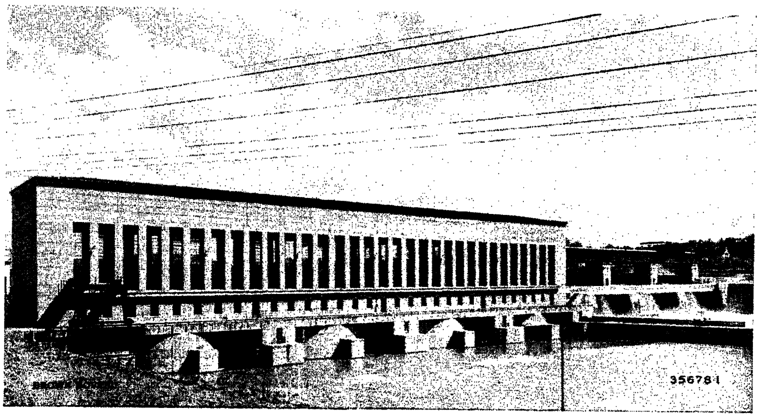


Fig. 36. — Ryburg-Schwörstadt Power Station. Machine hall from the tail-race side.

These generators, each of 23,000 kVA at 750 r.p.m., were built for the Piottino Power Station, Canton Tessin (Switzerland). The run-away speed, if the speed governor fails, of 1380 r.p.m. corresponds to 135 m/s at the periphery of the wheel, which brings it well within the peripheral—speed and material—stressing range for which turbo-generators are calculated. It may be mentioned that the specific pressure on the carrying-bearing of these units attains the considerable figure of 31 kg/cm^2, while the mean peripheral speed of the carrying bearing is 25·6 m/s.

Among these machines, the *generators to produce single-phase current for traction* occupy a special position. They form a difficult problem for the machine designer, mechanically, on account of their big dimensions due to the low frequency worked to as well as the fluctuating load and, electrically, because 15,000 V terminal voltage is called for, with one pole to earth. It may be said here that the traction generators built by us have never been the cause of any trouble and, from the very first, have given an excellent account of themselves, in service. The latest generators of this type being built, at present are the 18,000-kVA units at 500 r.p.m., 10,500 V, 16$^2/_3$ cycles for the Altenburg Power Station of the Etzelwerk Co., these are the first vertical-shaft four-pole single-phase generators ever built for the Swiss Federal Railways. They are not intended for direct supply of the 15-kV trolley wire and could, therefore, be designed for a lower terminal voltage. We will describe these

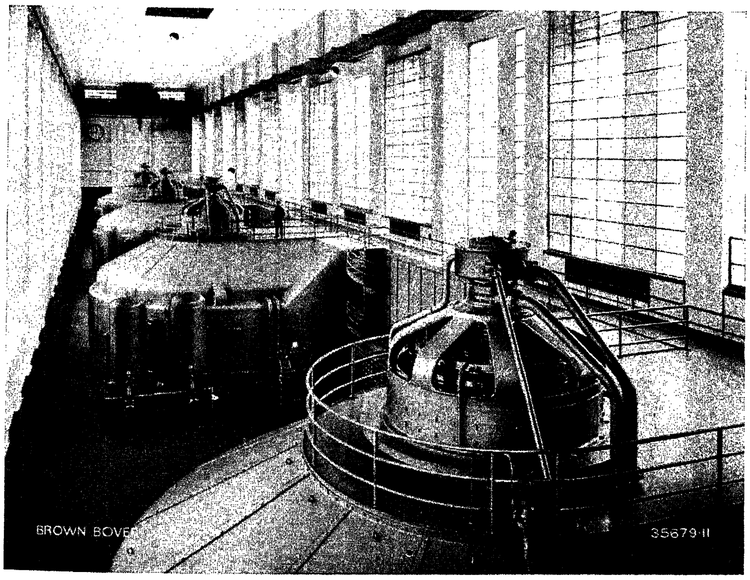


Fig. 35. — Ryburg-Schwörstadt Power Station.
Four generators each of 32,500 kVA, 75 r.p.m., 10,500 V, 50 cycles.

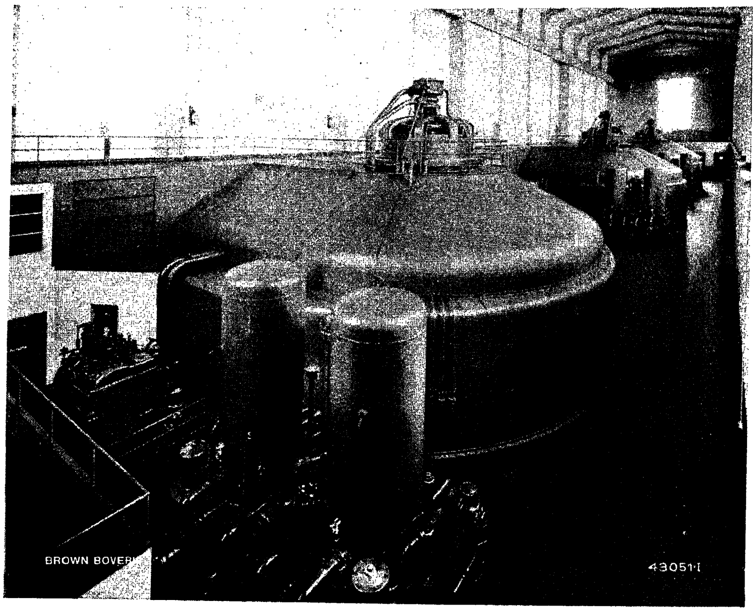


Fig. 37. — **Albbruck Power Station on the Rhine, of the Albbruck Dogern Co.** Three three-phase generators, each of 32,500 kVA, 10,500 V, 75 r. p. m., 50 cycles.

units in a later number of The Review and would only refer, here, to Fig. 41 which shows a half stator of one of them.

Among other interesting machines of this class built by us or by our concessionary companies in the course of last year, mention may be made of three horizontal shaft generators each for 18,750 kVA at 428 r.p.m., p.f. = 0,8, 11,000 V, 50 cycles; two horizontal shaft, three-phase generators each for 20,000 kVA at 504 to 600 r.p.m., p.f. = 0,75, 7600 to 8400 V, 42 to 50 cycles; two horizontal shaft, three-phase generators each for 5000 kVA at 750 r.p.m., p.f. = 0,9, 10,000 to 12,000 V, 50 cycles (Fig. 42 shows the stator of one of these machines).

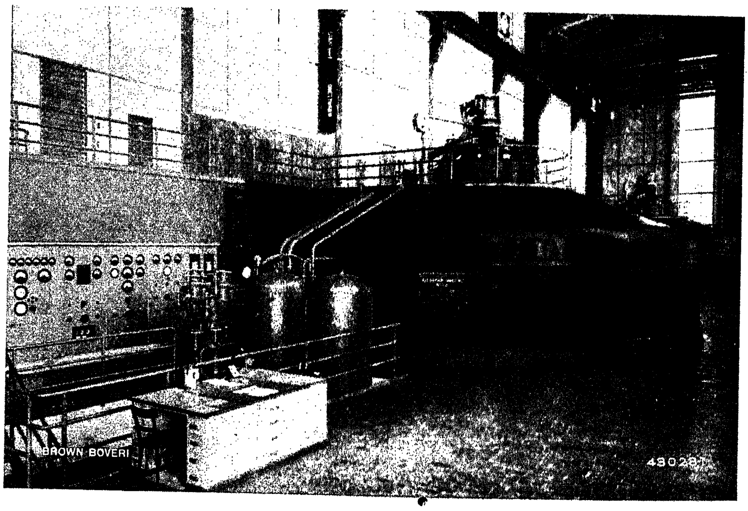


Fig. 39. — **Klingnau Power Station, of the Aare Werke Co., Brugg.** Part view of machine hall.

At the end of last year, one of our concessionary companies got an order for 15 vertical-shaft generators each of 5000 kVA at 115 r.p.m., 6300 V, 50 cycles for three new power stations. These will be the first generators in Europe placed in an outdoor power station.

2. *Big transformers.*

No fundamental changes have been introduced in the design of big transformers for supplying transmission lines. The practical application of new methods, however, have allowed of progress being achieved as regard reducing dimensions, and losses, cheapening manufacture with a simultaneous increase in service reliability.

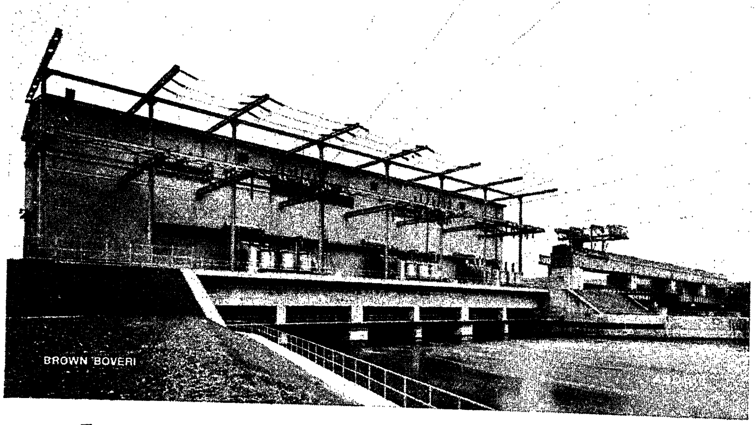


Fig. 38. — **Klingnau Power Station of the Aare Werke Co., Brugg.** View of the station with transformer plant from the tail-race side.

For building the laminated core, special low-loss laminations are available to-day, with a specific loss of only 1·1—1·2 W per kilogramme. The factor of space utilization as regards the cross sections of legs and yokes has been increased, thanks to there being available very big sizes of dynamo sheeting of absolutely flat surface and exempt from that waviness which made working on them so troublesome, formerly. Much subdivision of the legs into separate stacks of sheeting and the arrangement of the latter so as to form as nearly perfect circular sections as possible is

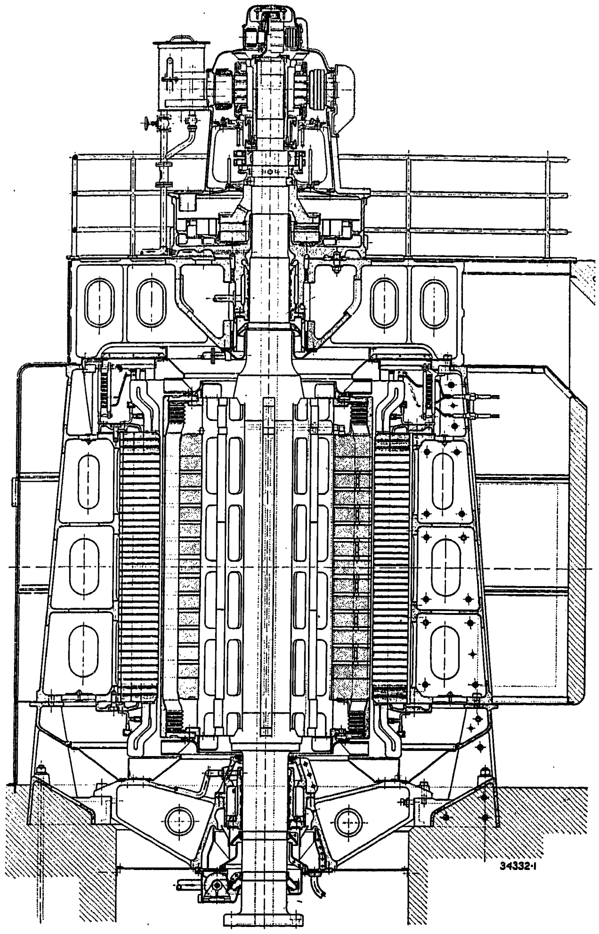


Fig. 40. — Monte Piottino Power Station. Three-phase generator, with cylindrical rotor, for 23,000 kVA, 750 r.p.m., 8200 V, 42/50 cycles.

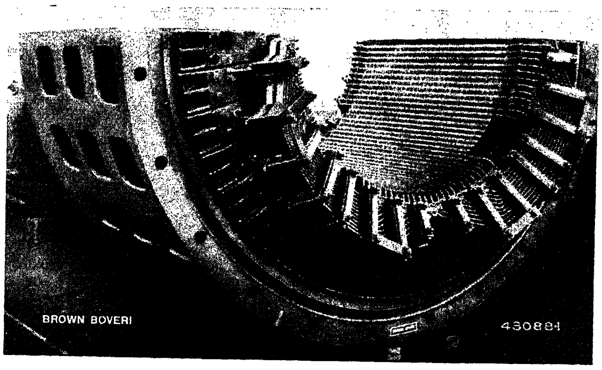


Fig. 41. — Altenburg Power Station of the Etzelwerk Co., Pfäffikon. Half stator of single-phase generator, 18,000 kVA, 10,000 V, 500 r. p. m., $16^2/_3$ cycles.

Transformers with external cooling of the oil in water-cooled refrigerators are, practically, only built, to-day, for completing or replacing units of the same type already delivered or in cases where heavy overloads have to be dealt with, in service. Two transformers of this type each of 16,000 kVA were delivered to Olten-Gösgen Power Station of the E. W. Olten-Aarburg Co., Olten (Switzerland). One of these steps up the generator voltage to 50 kV and the other either to 50 or 80 kV, as needed; the change-over from one high voltage to the other is carried out, the transformer being dead, by a switch operated from floor level. The 16,000-kVA transformer with interchangeable high voltage replaces a 7050-kVA transformer which we delivered in 1917. The progress made in transformer design during the intervening period is clearly shown up by the fact an improvement of the same order. One demand of the manufacturer which has not yet been satisfied by the steel works is for better magnetizing qualities of laminations in order to lower the no-load current absorbed; or an extension of the saturation point above 15,000 to 16,000 Gauss along with the former low-loss figures. The satisfaction of this demand would mean a double step forward, as the voltage per turn would be increased and the length of the coil reduced, as well.

The natural-cooling system for transformer oil is being chosen for ever bigger units, to-day, it means less running outlay as power and water for cooling are no longer required and, also, less supervision is need. The three transformers with natural oil cooling, each of 20,000 kVA, mentioned in our last year's report as built for the Klingnau Power Station of the Aarewerke Co., are now in service (Fig. 43). For transformers designed for natural or forced air-draught cooling, multiple-pipe type radiators are used, either built on (welded on) to the transformer tank or grouped in batteries. These pipe-type radiators give better cooling than corrugated-metal radiators, especially in outdoor stations.

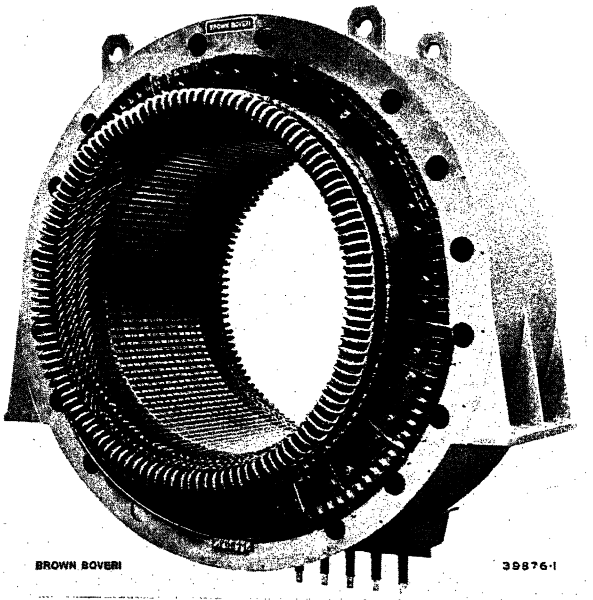


Fig. 42. — Pallivasal Power Station. Stator of three-phase generator for 5000 kVA, 750 r. p. m., 10,000/12,000 V, 50 cycles.

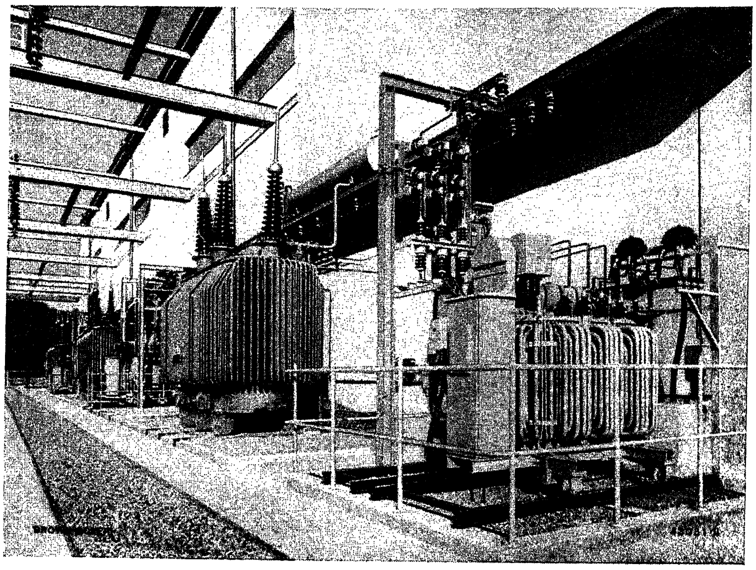


Fig. 43. — Klingnau Power Station of the Aarewerke Co., Brugg. Transformer plant.

that the active parts of the 16,000-kVA unit designed for more than double the output could be lodged in the tank of the old unit after it had been very slightly lengthened. In spite of having increased the load rating 2·3 times, the no-load losses were actually reduced to 65 % of the old value, total losses remaining about the same.

Bushing insulators up to 150 kV rated voltage are all built now to the wound condenser-bushing type with a porcelain sleeve and oil-filled porcelain bushings are only used for higher voltages.

After years of work and systematic investigations into the properties of raw material, we have been successful in reducing the electric losses of wound hard paper; this is thanks to the use made of a special high-grade artificial resin combined with an improved manufacturing process. Thus, in 1928, the loss figures for the best qualities of hard paper were still as high as about 1 watt/dm^3 at 10 kV/cm, 50 cycles, and 90° C, while, to-day, it is standard practice to attain 0·2 to 0·3 watt/dm^3. Bushings built up of wound material of this kind are absolutely proof against a heat break-down at a temperature of 90° C, under a voltage up to 250 kV applied between earth and line and at 50 cycles. The progress in the design of the bushing has kept step with that of the insulating material. The designs have been adapted to the needs of modern service and the requirements of manufacturers. All cemented joints are eliminated. Reliable, flexible intermediate organs take up the expansion due to heat. Oil-tight connections are, now, only made of sealings which can be retightened when required or such as are kept under constant pressure by some elastic organ. All the bushings allow of tappings for voltage measurements and the synchronization of systems.

The much more extensive knowledge possessed, to-day, on lightning has also been used in bushing design.

Among other big transformer units built last year, or building, by us or by our concessionaries, mention may be made of the regulating transformer for the Gösgen Power Station, of 32,500 kVA, 167 ÷ 138 kV/48,5 ± 23 × 0·82 kV, combined with our new on-load tap changer, of which mention is made further on; two three-winding transformers each for 5000 kVA, 11,000 V/11,000 V $\pm 2^1/_2$ % and ± 5 %/66,000 V $\pm 2^1/_2$ % and ± 5 % for the Pallivasal Power Station, Travancore, India (Fig. 44); a three-phase transformer with external oil cooling by water for the Amsterdam Electricity Works, built for 35,000 kVA, 50,000/10,600 V; two three-phase transformers for outdoor erection and natural cooling each for an output of 15,000 kVA, for Uddeholms A/B, Munkfors; a reg-

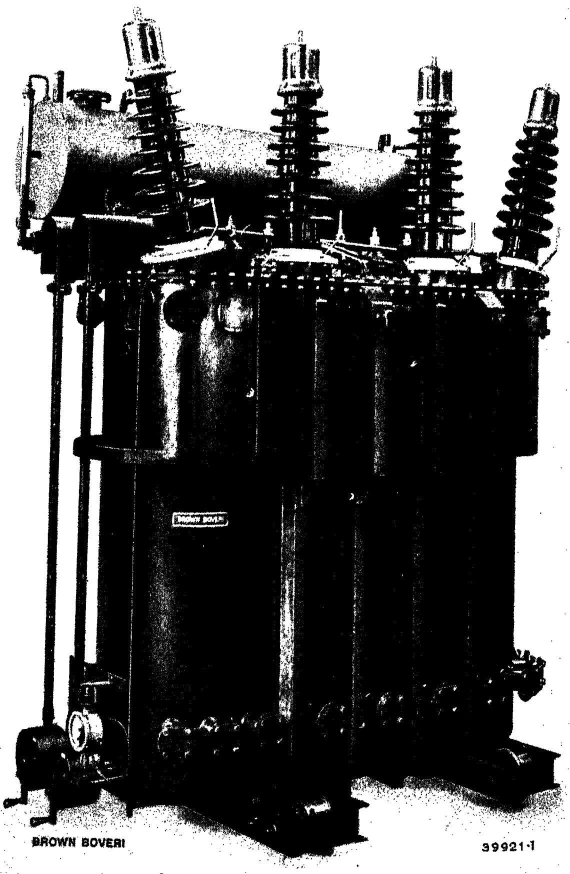


Fig. 44. — Pallivasal Power Station. Three-phase three-winding transformer for 5000 kVA, 11,000/11,000/66,000 V, 50 cycles, seen from the high-voltage side.

ulating transformer of an output of 40,000 kVA, 6420/111,000 $\pm$ 8 $\times$ 2350 V and another unit for 20,000 kVA, 112,000/55,000 $\pm$ 6 $\times$ 1370 V, etc.

Fig. 45 shows one of the transformers 35,000 kVA, 10·5/104 kV, 50 cycles for Albbruck-Dogern Power Station; this unit was mentioned in our last year's report and has now been put into service.

3. *Circuit breakers.*

When on the subject of circuit breakers we said, in our former reports, that we were of the opinion that it was a mistake to try to influence arbitrarily the development of circuit-breaker design. That being our conviction, we carefully avoided taking any stand in favour of any one of the three types of breaker, namely those using oil, air or water as extinction mediums. We began by making use of every means our high-power testing plant made available to develop, simultaneously, all three breaker types by investigating the physical process at closing and opening of the breaker, under oil, water and compressed air, as we were convinced that practical experience alone would give the right answer.

Developments during the last twelve months have amply justified us in this attitude. Thanks to the results of investigations made, the oil circuit breaker has been developed to a stage where it can rightly be termed an excellent and reliable apparatus, both simple and cheap. A series of constructive improvements have practically eliminated its fundamental weaknesses. However, the oil-circuit breaker is dependent on oil as an extinction medium for the arc and a growing distrust of oil, which we think is often a matter of sentiment, has been gradually becoming evident, due to the inflammability of the filling. This sentiment had be reckoned with by the manufacturer.

We, therefore, took up the construction of *water circuit breakers* without, however, ceasing our efforts to develop the oil circuit breaker or giving it a second place in our investigations. We were satisfied that with the water-circuit breaker we had definitely banished the danger of fire or noxious fumes but not the possibility of the breaker chamber bursting; this latter danger could, however, be overlooked as the results would not be disastrous and would be localized. There are certain difficulties in switching operations with the water circuit-breaker under very high and very low currents; these have been overcome, but at the cost of rather expensive improvements to the breaker design. To this must be added the disadvantage of water not being a perfect insulator, which limited the field of utility of this breaker to 30—40 kV. Even at these voltages, water circuit breakers can only be built if certain determined constructive relations are observed and these breakers must be carefully supervised in service.

Conditions change entirely when oil replaces water in breakers designed to this principle and used in high-voltage outdoor stations. The advantages of this particular breaker design become at once apparent and this caused us to develop the breaker of small oil capacity or *convector circuit breaker* mentioned and described, here, on several occasions.

It may be recalled that the oil filling which would otherwise be some tons for the highest voltages is reduced to relatively few litres. As the following table shows, the duration of the arc in

TABLE III.

Switching times of high-voltage circuit breakers for over 110 kV.[1]

Type of breaker	Year built	Rupturing time in s	Duration of arc in s
Multi-gap oil circuit breaker Type AF	1925	0·3	0·2
Multi-gap oil circuit breaker Type OVF	1930	0·23	0·12
Oil circuit breaker with convectors, Type OKF .	1934	0·17	0·07
Convector circuit breaker, Type R	1934	0·15	0·03÷0·05

[1] The figures in the table are highest values and can be considerably lower, according to the operating voltage.

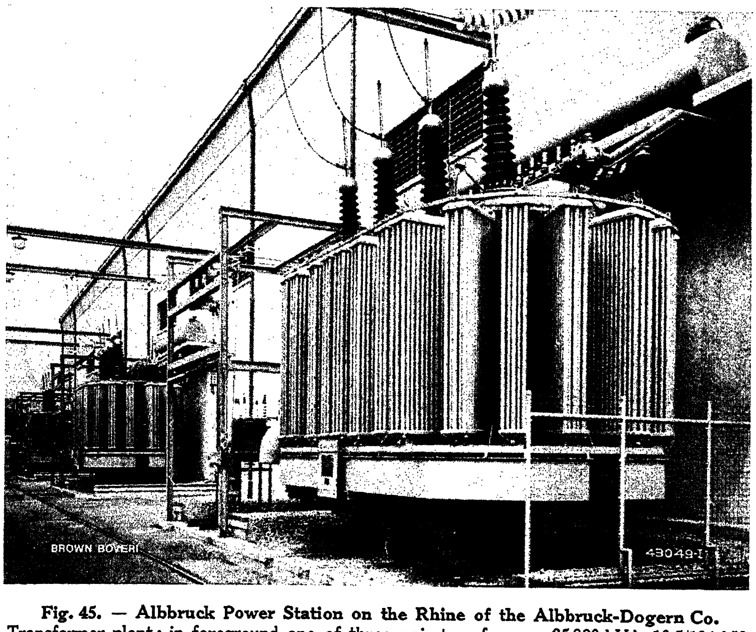


Fig. 45. — Albbruck Power Station on the Rhine of the Albbruck-Dogern Co.
Transformer plant; in foreground one of three main transformers, 35,000 kVA, 10,5/104 kV, 50 cycles.

high-voltage oil circuit breakers of old design, which is 0·2 s is now reduced to 0·03÷0·05 s in convector breakers and this corresponds to a reduction of the switching duty proper which justifies the big reduction of the oil filling.

The time for rupturing the arc, which was still 0·3 s in 1925, was reduced to 0·23 s in 1930 and again reduced to 0·15 s in the convector breakers built in 1934.

The reasons of the exceptionally successful results attained with the convector breaker are to be sought in the very high speeds imparted to relatively light contact rods and, chiefly, to the very efficient cooling of the arc, a direct result of the vigourous convection effect imparted to the oil. The extinguishing capacity of former high-voltage oil circuit breakers was some hundreds of volts per cm of length while it attains some thousands of volts in the convector circuit breaker. It should be recalled here that in every extinguishing process in which extinguishing proper is brought about through the agency of the heat developed by the arc itself, there is a range of critical current strength at low currents as regards arc extinction while, for the highest currents, a limit pressure is reached. These two limiting phenomena must be reckoned with in the design, when the breaker is built on the principle of arc extinguishing through the power lost by the arc itself. We have designed and built our convector chambers so that satisfactory and absolutely uniform results are attained over the whole range of current strength. It is certain that the convector circuit breaker is a very complete and satisfactory solution of the problem of high-voltage circuit breaking. Here, the fundamental weakness of the oil circuit breaker is, practically, eliminated, firstly, because of the small oil filling and, secondly, because the breakers are of the purely high-voltage type which are, almost certainly, wanted for outdoor stations only.

We and our concessionaries have already built a considerable number of *convector circuit breakers* up to the highest voltages, for very important plants, this after the first breaker set of this type was first put to work about two years ago. There is, therefore, ample experience available, to-day, and all report received are most satisfactory, including those of plants working under very unfavourable climateric conditions. The operating organs and disconnecting switch movements are governed by rods made of tough fibrous material protected from the weather by porcelain sleeves. This very reliable mechanical method of transmitting the movements to the breaker has been the object of some criticism in certain quarters, the suggestion being put forward that insulated rods of organic material are not really impervious to atmospheric conditions. It is obvious that we give problems of this kind our closest attention before passing on to the constructive stage. *Dr. Thum*, Prof. of Darmstadt Institute of Technology, was the first to demonstrate, brilliantly, that, practically, of all defects of the mechanical construction, inherent weaknesses in the design of the parts themselves are of far greater importance than the question of material. The same applies, exactly, to the electrical strength of the apparatus.

It is remarkable how many designers there are who have not comprehended the truth of this.

We have tested insulating rods properly designed as regards electrical and mechanical rigidity and have done so in continual service for about two years under 3 to 5 times the rated voltage and working under quite the same conditions, out of doors, as they would in service. Under this prolonged test, the stressing was as high as about 10 % below the flash-over voltage. Despite the strongest sunlight and heat, despite rain, fog, frost and snow, none of these rods showed the slightest sign of a surface change after two years, and it is, therefore, quite obvious that no defect developed in the said rods during these two years of very severe and continuous testing. Taken as a whole, the completed test is a splendid example of the importance to be attached to proper electrical rigidity of design. It is, therefore, no accident if the results we get in service are so good, because the stressings to which the

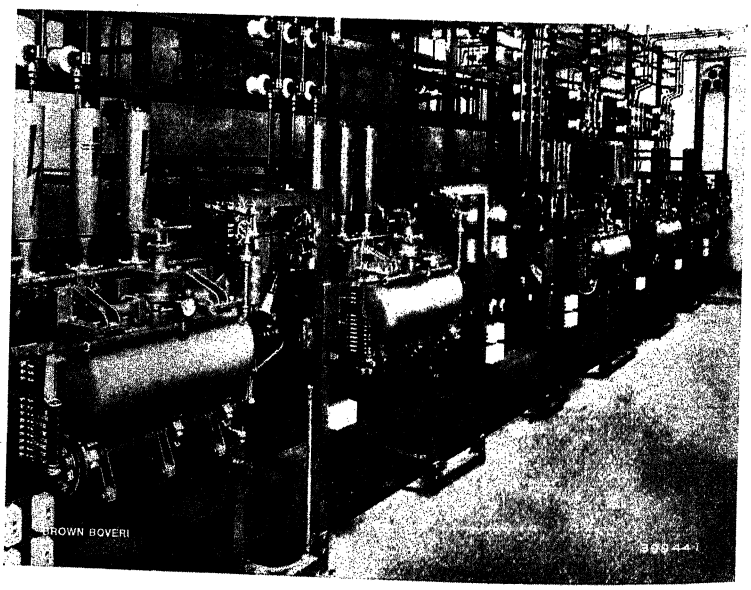


Fig. 46. — Winterthur Electricity Works. 12 air-blast high-speed circuit breakers Type D 64 i 100, voltage rating 6·4 kV, service voltage 3·3 kV, current rating 400 A, rupturing capacity rating 100 MVA.

rods are submitted in ordinary service are only a fraction of those stood up to in the two-years test.

This has proved, without a doubt, that our design is superior to any other existing one using ceramic bodies to transmit movements and in which these

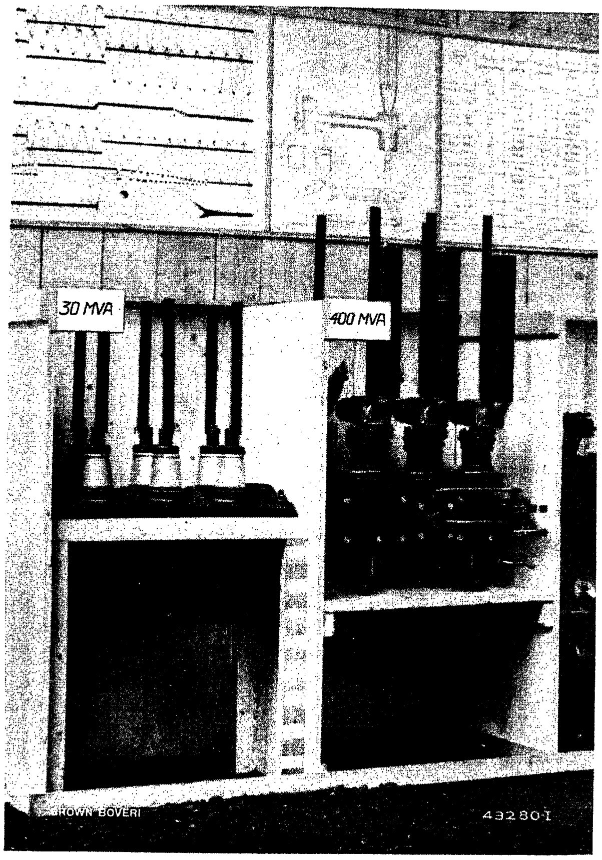


Fig. 47. — Air-blast high-speed circuit breaker for 400 MVA, rupturing capacity as compared to an oil circuit breaker of old design for 30 MVA rupturing capacity.

organs are subjected to very deleterious sudden mechanical movements, which go so far as even to include torsion.

There is still a very encouraging demand for our *single-tank three-pole oil circuit breakers,* for 87 and 110 kV with convector chambers, which were mentioned in our last-years's report. Thus, 25 such breakers for 110 kV and 400 A rated current, 1000 MVA rupturing capacity, with their driving columns and power-storage drives were ordered by the Tasmanian Hydro-Electric Commission.

The increasing use made of compressed air for power-storage drives and for all kinds of operating mechanisms naturally led to the idea of using it for the extinction of the arc. There were many big advantages inherent to the use of compressed air in breakers, namely:— the extinction capacity of the medium is always uniformly strong and does not become combustible and explosive, like the oil does in oil circuit breakers by the passage of the current and the current rupturing phenomenon; then, there are no critical current ranges to be feared in air-blast circuit breakers, as they are termed. These reasons caused us to make a first test with an *air-blast breaker,* as early as 1922, which was not followed up however, at that period, owing to the lack of proper testing facilities. It was only after our high-power testing plant was built that systematic investigations on the air-blast breaker could be taken up.

To-day there is a complete series of 9 types of new air-blast circuit breakers, up to rated voltages of 64 kV which have been termed air-blast high-speed circuit breakers owing to their remarkably rapid current-breaking times; for each rated voltage, there are breakers available of different rupturing capacities. We would refer to the article which appeared in the November number of The Review, 1935, on the subject of these breakers which gives a detailed description of the design and method of operation of the new air-blast high-speed circuit breaker and we would only summarize as characteristic qualities of our air-blast high-speed circuit breakers the facile maintenance, simple design, great reliability, efficient air-tightness, low consumption of compressed air, relative silence, little contact burns, exemption from danger of fires or explosions or the formation of noxious fumes, rapid switching times, simplicity of installation and erection.

Our air-blast high-speed circuit breakers are so designed that one closing and opening operation can still be safely carried out under the minimum air pressure admissible. The air pressure then sinks to about $^2/_3$ of its former value but attains its full-rated value again within a few seconds as a result of the breaker being connected to the compressed-air plant. Apart from two electro-pneumatic control valves, there is only one air-control valve for all three poles.

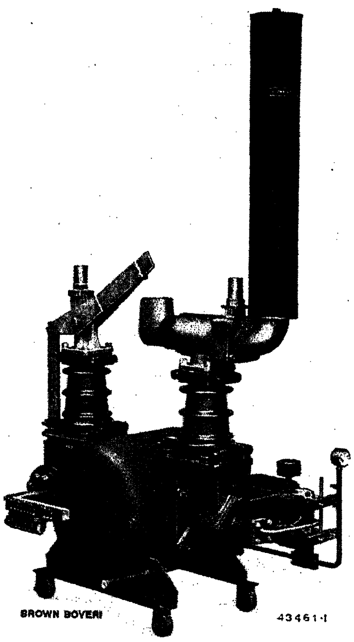


Fig. 48. — Single-pole air-blast high-speed breaker, 15 kV voltage rating and 500 MVA rupturing capacity.

The drive is pneumatic. In breakers for remote control, the two control valves are solenoid-operated and can be equipped with the most simple apparatus. Suitable interlocks prevent any kind of faulty switching.

We and our concessionary companies have had the opportunity of building a great number of air-blast high-speed circuit breakers of this series; the erection of 12 three-pole breakers of 6·4 kV rated voltage for the Electricity Works, Winterthur (Switzerland) may be mentioned (Fig. 46). The putting up of a single-pole air-blast high-speed breaker in the Amsteg Power Station of the Swiss Federal Railways is especially interesting as it is placed at one of the most vital points on the railway-supply system (Fig. 48). This breaker replaces an oil breaker and is meant to work ordinarily as a supply-point breaker for the trolley wire, for which duty it must have a rupturing capacity of 100 MVA. Under given service conditions, however, the breaker must be able to feed the trolley wire directly from the bus-bars of the power station, under which conditions the possible rupturing load when breaking a short circuit attains about 500 MVA, an exceptionally high rupturing capacity to demand of a single-pole breaker. The maximum closing current may exceed 120,000 A.

Fig. 47 shows that an air-blast high-speed circuit breaker of our design, for 400 MVA rupturing capacity, does not take up any more room than an oil circuit breaker of only 30 MVA of old design.

Another interesting development, in this field, was the erection of four three-pole air-blast high-speed circuit breakers in the Olten-Gösgen Station of the E. W. Olten-Aarburg Co., for 11 and 50 kV rated voltage, 1000 and 400 A rated current and 400 and 600 MVA rupturing capacity.

Mention should also be made of the development of a three-pole air-blast high-speed circuit breaker for 6·4 kV, 640 A rated current and 100 MVA rupturing capacity which is built into an automatic compressed-air producing plant.

TABLE IV.

Switching times of three-pole high-voltage circuit breakers, 6·4 to 37 kV.

Circuit breaker Type	Year built	Rupturing time in s	Duration of arc in s
AV, oil circuit breaker with solenoid contacts . .	1925	0·25	0·08
O and OV, oil circuit breaker with wedge contacts . .	1929	0·1	0·05
U, water circuit breaker	1932	0·1	0·03
D, air-blast circuit breaker	1935	0·05	0·01

The progress made in circuit breaker design since the year 1925 is best shown by the reduction of rupturing time and duration of the arc (see Table IV).

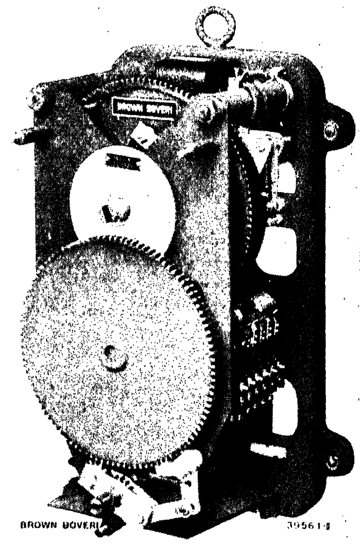


Fig. 49. — Power-storage drive Type Q 1. Torque 7·5 mkg.

The *power-storage drives* which are the most suitable form of drive for all types of circuit-breakers, have been improved from the constructional point of view and the standard series of the said drives increased by one more, for 7·5 mkg torque (Fig. 49), so that we have now available four standard types, from 7·5 up to 120 mkg torque. All these are designed on the some principle.

4. *System regulation.*

Among the problems inherent to system regulation, those regarding *maintenance of frequency* and *load regulation* take first place. To solve this problem, we have created a combination of frequency regulator and output-programme regulator. The duty of the frequency regulator is to make the static character of the turbine governor — necessary in order to attain the right watt load — inoperative as regards the external circuit and thus to maintain the mean frequency within a narrower range than heretofore. The output regulator has as duty to allow the machines to work, on one or several outgoing lines, either to constant load or according to whatever load programme is desired. Thus, the arrangement can be so set that each machine in a power station works either on frequency or on load, or on a combined load-frequency programme.

The frequency regulator is a new regulator developed from our well-known automatic voltage regulator, its excitation winding is connected to the

network voltage through a capacitance and inductance, so as to form a kind of resonance circuit. Its sensibility is of the order of 1/100 cycle. As in big power stations, for which these devices are exclusively intended, there are always several machines working in parallel, on account of the size of the load, the frequency regulator cannot influence the turbine governors directly but only through load-regulators. The object of the load regulators is to distribute the load evenly or according to some desired ratio between the generators working in parallel. The load regulators are output regulators with three windings. The first two, a voltage and a current winding, are connected to the generator measurement transformers, in wattmeter connection while the third winding is influenced by the frequency regulator. Both winding systems exercise opposite torques on the moving system, which torques are balanced under normal conditions.

The output-programme regulator is composed of an ordinary recording wattmeter on the paper roll of which the daily diagram is given by two parallel lines drawn in graphite powder. Two electrone tubes, the grid voltages of which are governed by needles which glide on the daily diagram, actuate two relays which, on their part, influence a motor which governs potentiometers to which the load regulators are connected.

It is thus possible for some machines of a power station to regulate the frequency of the system on which they work while the other machines work to a programme or to constant load on the same or on another system.

5. *Relays.*

In our last report we mentioned that our former *definite time series relay* to be directly fitted on breaker terminals had been replaced by a more modern one, which had met with much success, in practice, on account of the unsurpassed precision it gave in tripping to the times set to. The next step was the development of a new *current-indicating secondary relay* which is shown in Fig. 50. The December number, 1935, of The Review gave a detailed description of the design and mode of operation of this relay so that we can limit ourselves to summarizing its most *important qualities.*

The power consumption is only 8 VA as against 47 VA in the former type, both referred to the minimum pick-up current. The time lag of the relay can be set between 0·2 and 10 s, is independent of the strength of the current and has an error of only $\pm$ 5/100 s as referred to the time setting. The range of adjustment of tripping current is 1 to 4 times the rated current. The relay is also fitted with limit current instantaneous tripping which can be adjusted between 3 and 5 times the rated current or else can be blocked; the relay has special terminals to allow of testing it in service without dismantling it. All the setting organs necessary to service are visible and easy to get at, by opening the glass cover. A very remarkable innovation is the current-indicating by a built-in ammeter. Often, this device allows of doing away with special ammeters and it also forms a signalling device to show, at all times,

TABLE V.

Brown Boveri maximum-current relays.

	Old type	New type
Series relay		
Shortest time setting	1 s	$0 \div 0{\cdot}3$ s
Time error	0·55 s + 5% of time setting	$\pm 0{\cdot}1$ s
Current setting . .	$1{\cdot}4 \div 2$	$1{\cdot}2 \div 2$
Short-circuit strength	150 times rated current	$500 \div 1000$ times rated current
Secondary relay		with current indicator
Shortest time setting	1 s	0·2 s
Time error	0·55 s + 5% of time setting	$\pm 0{\cdot}05$ s
Current setting . .	$1{\cdot}3 \div 2$	$1 \div 4$
Consumption of relay	47 VA	8 VA

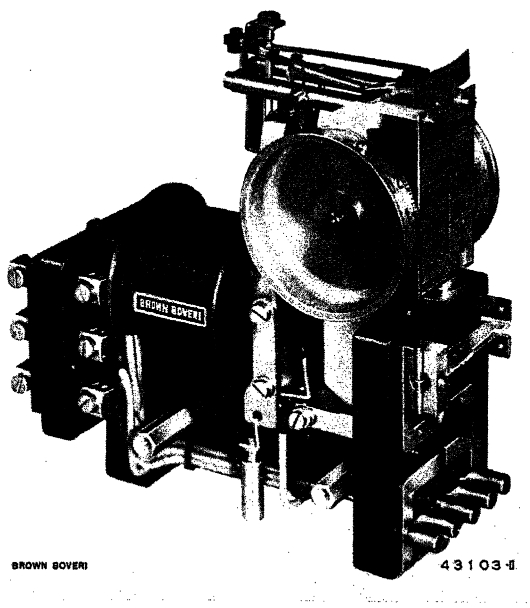


Fig. 50. — Current indicating secondary relay.

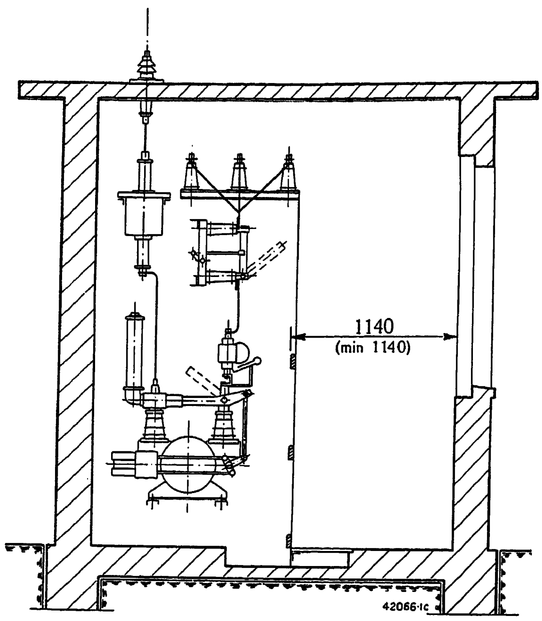


Fig. 51. — Switchgear cell equipped with air-blast high-speed circuit breaker of 11 kV rated voltage, 250 MVA, rupturing capacity. Breaker mounted in horizontal position.

if the relay is ready to work, without requiring any continually rotating parts for this duty.

The relay is built into a casing the size of which corresponds to that of our relays built up till now; it is, thus, possible to exchange an old relay for a new one, without any difficulty.

The summary on page 27 shows what an advance has been achieved by our two new relays, namely:— the new definite time series relay and the new secondary relay.

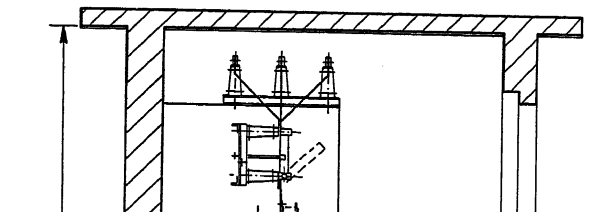


Fig. 52. — Switchgear cell equipped with air-blast high-speed circuit breaker of 11 kV rated voltage, 250 MVA, rupturing capacity. Breaker mounted on the partition.

6. *Switchgear plants.*

Simplicity and ease of supervision have continued to be the hall-marks of our switchgear plants, built in the course of the last year. The personal inclinations and desires of clients have been more and more influenced by the importance of these guiding principles. The former layout of bus-bars, disconnecting switches, circuit breakers in separate chambers is rarely used, to-day. Our point of view that all apparatus belonging to one bus-bar subdivision should be lodged in the same room and in such a way as to be supervised from the control station is becoming generally recognized as the right one. The open layout used for the higher tensions, without partitions to form cells for outgoing leads from bus-bars, is often used now for average-voltage ranges. This solution offers the maximum of simplicity and ease of supervision and has, really, come into its own with the introduction of the air-blast circuit breaker. Sliding lattice doors or partitions are put

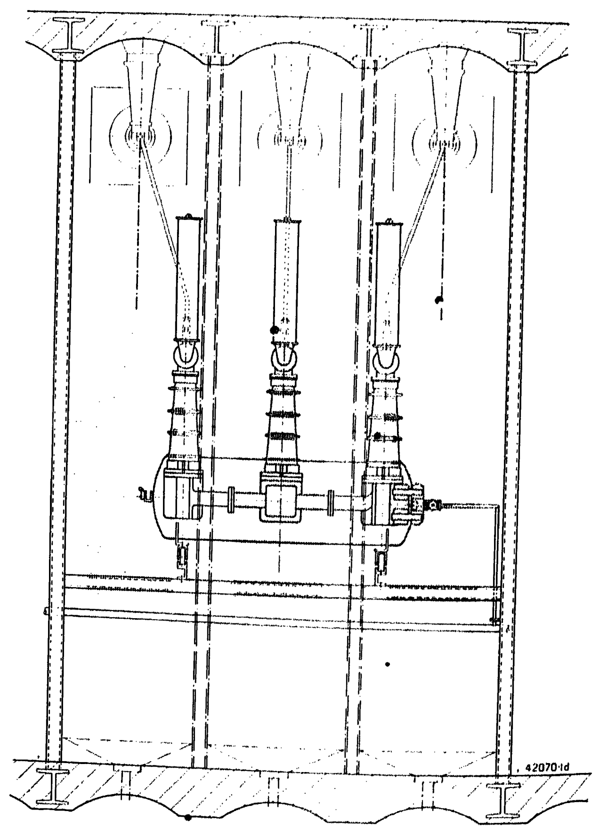


Fig. 53. — Replacement of a 50-kV three-tank oil circuit breaker set, delivered about 20 years ago, for indoor erection, by an air-blast high-speed circuit breaker of 600 MVA.

up, during repairs or revision work, to shut off whatever sections are to be isolated.

While oil and water breakers could only be erected horizontally, air-blast breakers can be mounted in any position suitable to the plant. Formerly, the switchgear plant had to be made to suit the breakers but now, with air-blast breakers, these plants can be better built to meet the object to be fulfilled and the available space:— the air-blast breakers are adaptable in every case (Fig. 51 and 52).

The different ways in which they can be built in and their compact design allows of putting air-blast high-speed breakers in old plants where oil circuit breakers were before and thus of increasing

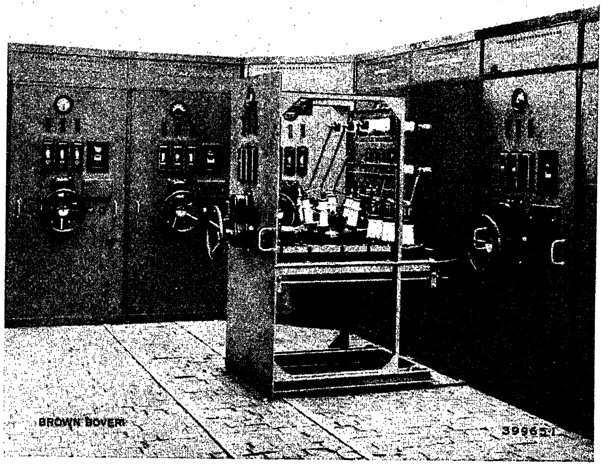


Fig. 54. — Pallivasal Power Station. Iron-clad switchgear plant, 11 kV, with switch truck to be run in and out, showing a truck quite run out and the closing-off doors shut.

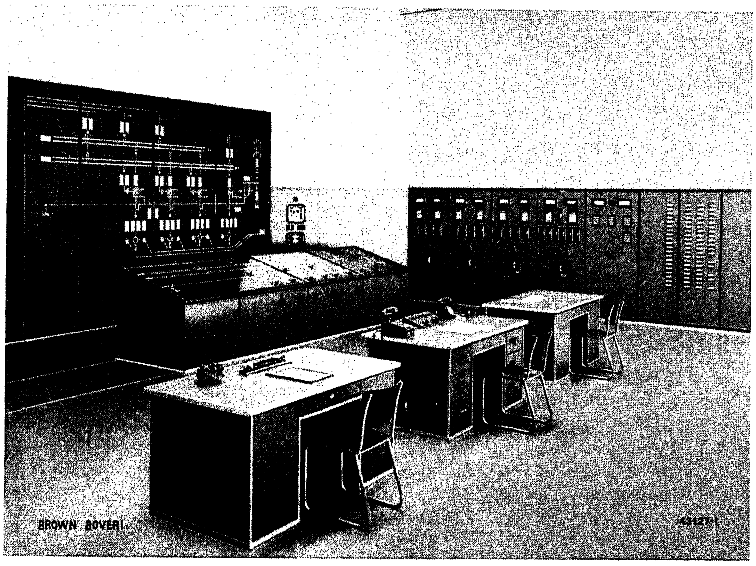


Fig. 55. — Chandoline Power Station of the La Dixence Co. Control desk with light diagram.

the reliability and rupturing capacity of the plant (Fig. 53).

The compressed-air generator and compressed-air distributing plant do not constitute an undesirable secondary plant. Further, compressed air can be made to fulfil a number of other duties, such as operating disconnecting switches, valves, etc.

We have always refused to take up the building of cast-iron clad high-voltage plants using insulators filled with oil or some solid mass, of that type which attained a certain popularity in earlier years, our reasons being the danger of fire and explosions which we consider they offer. On the other hand, our concern has developed various switchgear panel designs for the same purposes but with air insulation and used them successfully in practice; they have the only disadvantage of being rather heavy and expensive. In the course of last year, however, we successfully developed a lighter and simpler design (Fig. 54). The principle we recognized as the right one of insulation by air of bus-bars and lines has been maintained and oil and solid fillings are eliminated.

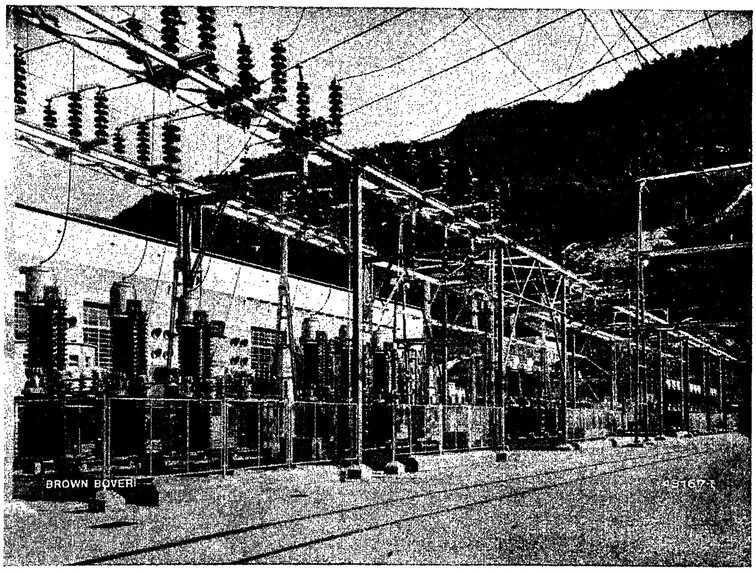


Fig. 56. — Chandoline Power Station of the La Dixence Co. Part view of 135 kV outdoor switchgear plant with 135-kV convector breakers.

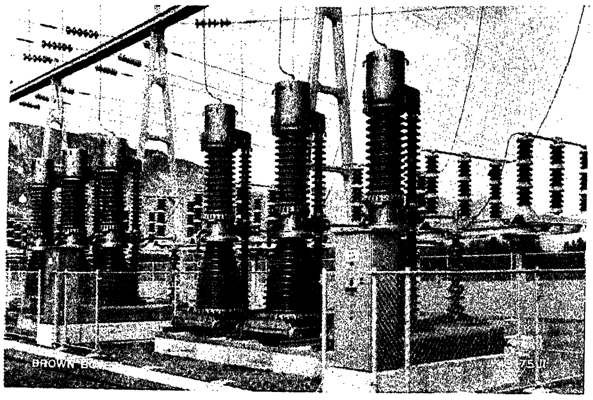


Fig. 57. — St. Triphon Substation of the La Dixence Co. Convertor circuit breaker set, 135 kV.

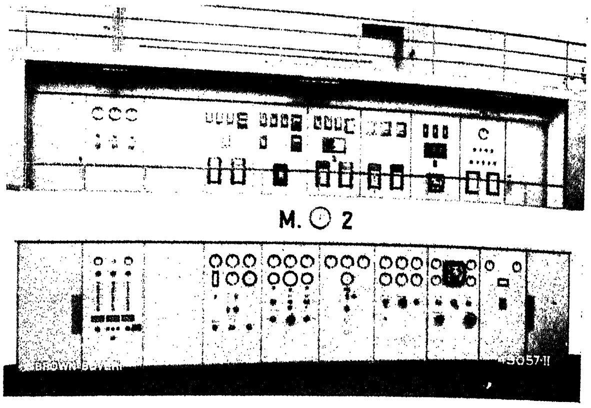


Fig. 59. — Albbruck Power Station on the Rhine of the Albbruck Dogern Co. Switchboard of the generators.

All apparatus is mounted on removable trucks. The current-carrying parts are shut off from contact by welded steel shutters after the truck has been run out or run in. Oil circuit breakers can, also, be used, if called for by the client; however, air-blast breakers make the enclosed switchgear unit lighter and easier to handle.

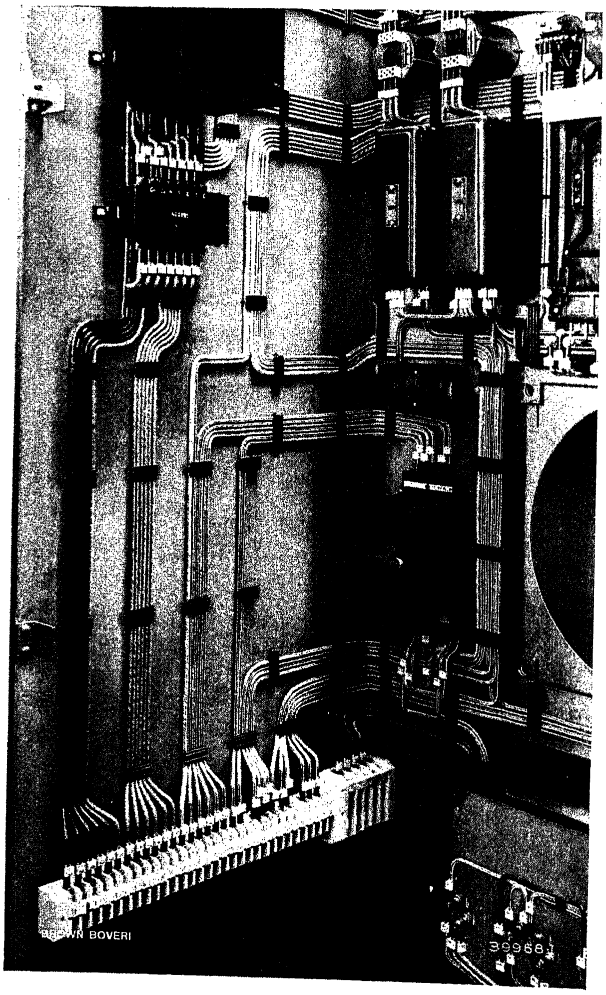


Fig. 58. — Pallivasal Power Station. Main switchboard. Details of wiring layout at the back of a generator panel.

In earlier days, it was principally symmetry which was sought in the arrangement of the control apparatus and instruments on a switchboard while, to-day, the tendency is to place the apparatus to be read in the place to which it belongs on a mimic diagram shown on the main board. These mimic diagrams require fewer indicating plates and are simpler, more pleasing to the eye and easier to read than were the old types of switch panel. The *light diagram* is the most complete expression of the mimic diagram. Fig. 55 shows the control desk and light diagram of the Chandoline Power Station. This shows clearly that it is perfectly possible with light diagrams to reproduce in a small room and perfectly clearly a very big switchgear plant along with the hydraulic plant belonging thereto. Another part of the Chandoline switchboard plant, which we delivered complete, is that of the St. Triphon Substation shown in Fig. 57; this switchgear plant is one of the biggest and most interesting of its kind built recently. In our last report, we showed switchgear plants with convector circuit breakers mounted on high frames, while in this plant these breakers are on low pedestals.

The rear as well as the front of switchboard plants has been the object of improvements, during the last year. The open and simple layout of measurement leads, the simple way of designating terminals and our standard terminal plates which can be mounted side by side make for quick erection and reduce connecting faults to a minimum while making for simplicity when it comes to investigating trouble (Fig. 58).

Fig. 59 shows one of the machine switchboards in the Albbruck-Dogern Power Station.

II. POWER DISTRIBUTION AND CONVERSION.

A. TRANSFORMERS.

The improvements in the design and construction of transformers of medium and big outputs, for power stations, touched on in a preceding paragraph, all apply to transformers for substation plants, as well. One general difference is that, while power station transformers are usually equipped with tap changers allowing the voltage ratio to be altered within a relatively narrow range, transformers for substations are being equipped, in ever-increasing numbers, with on-load tap-changing switches. About $^3/_5$ of the high-voltage transformers turned out by us, last year, have built-in on-load tap-changing switches, a proof of the reliability of the latter apparatus.

In order to attain symmetry and great mechanical rigidity, the regulating windings are, usually, wound and treated by a special process. The designs with thread-type windings are based on the experience we gained in building generators, with parallel and transposed bars.

The following interesting transformers may be mentioned among those delivered to coupling stations and distributing substations:— 3 regulating transformers with 3 windings, for 110, 88 and 11 kV for Creek Road Substation, Hobart, for the Government of Tasmania Hydro-Electric Department. These outdoor transformers, with natural cooling, are designed for a carrying capacity of 25,000 kVA between the 88 and 110-kV windings and a load proper of 10,000 kVA on the 11-kV winding. The middle and the low voltages can be regulated under load.

In connection with the prolongation of the Gothard overhead transmission line, we got an order from the A. G. Elektrizitätswerk Olten-Aarburg for a 32,500 kVA transformer. This will be lodged in the new Olten-Gösgen outdoor station; the no-load ratio of the main windings is 167,000/48,490 V and this can be modified in 23 steps of each 820 V on the low-voltage winding by means of a star-point tap-changing switch without the transformer having to be cut out.

As to the tap-changing switches for building in to the oil tank, which we developed in 1928, for all voltages encountered in practice, about 400 three-pole units have been delivered; we have carried out some modifications on this type of apparatus to meet the latest requirements.

The new *tap-changing switch* (Fig. 60), as used on the transformer in the Olten-Gösgen outdoor station, just mentioned, is composed of sparking switch, bushing insulator, step selector and driving mechanism. The sparking switch is placed outside the transformer, being built on to the bushing insulator. The three switching elements per phase are opened by cam discs and closed by the action of strong springs. Here we use the same sparking contacts as before which have given a good account of themselves in practice. These are oil immersed for currents over 250 A and voltages over 37 kV and air-insulated for lower currents and voltages, in which case silver contact pieces are being used.

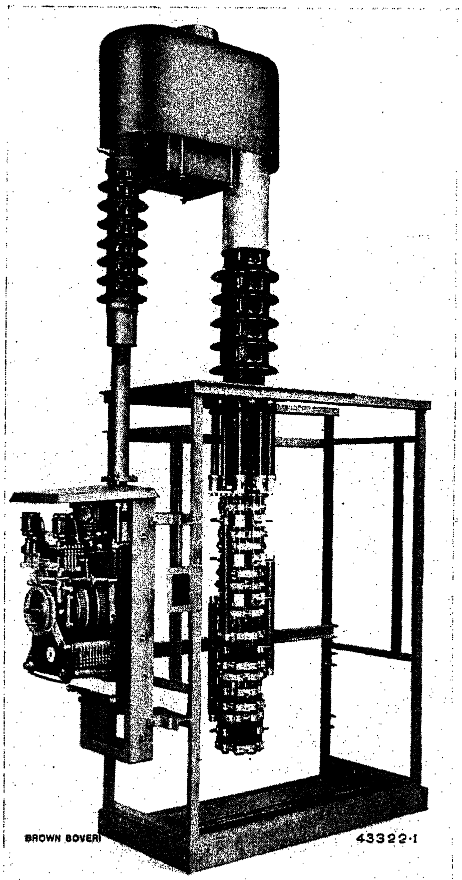


Fig. 60. — Tap-changing switch for star-point regulation, composed of a coarse and a fine selector, 64 kV rated voltage, 640 A, with power-storage drive.

According to the number of taps, the tap-changing switch is subdivided into a finely-graded selector and a coarsely-graded selector. The former has a maximum of seven steps. For a very big number of taps one, two or three coarsely-graded selectors can be built on, for a total of 15, 23 or 30 taps respectively. The moving current collectors of the selectors have rolling contacts which run, practically, without friction.

Both sparking switch and tap selector are actuated by the same drive; they are connected by a shaft passing down the middle of the insulator. This rigid mechanical interlock results in the operations on the contacts always taking place in the correct sequence, faulty switchings being eliminated.

The tap resistances are connected up for a fraction of a second, only and are therefore small, being lodged under the hood of the sparking switch.

A spring type of power-storage drive is used which gives absolutely reliable switchings and no stopping in an intermediate position. The spring is wound up by hand or by a motor. Hand drive, however, is only recommendable under roof and for small units, when the purchase price is of prime importance.

In tapping transformers with a regulating winding delta-connected, or in regulating transformers with windings in auto connection, three single-pole switches (phase tap switches) are required, as before. With separate star-connected windings the taps are placed on the common star-point side. Owing to the small difference of voltage between the different phases, this allows of combining the sparking switch and the tap selector, so that only one bushing insulator is required (star-point tap-changing switch).

By subdividing the tap selector into coarse and fine steps, the number of taps on the regulating winding can be made smaller than the number of taps. To attain 23 regulating taps, for example, only 7 fine and 2 coarse taps are required, in which the voltage range of a coarse tap must correspond to 8 fine selector taps. Another advantage of this subdivision is that the whole regulating voltage does not appear between two neighbouring contacts located on the circumference. This allows of reducing the insulating clearances which is very advantageous, in view of the small dimensions of the whole tap changing switch which has to be compact, as it is to be lodged in the transformer.

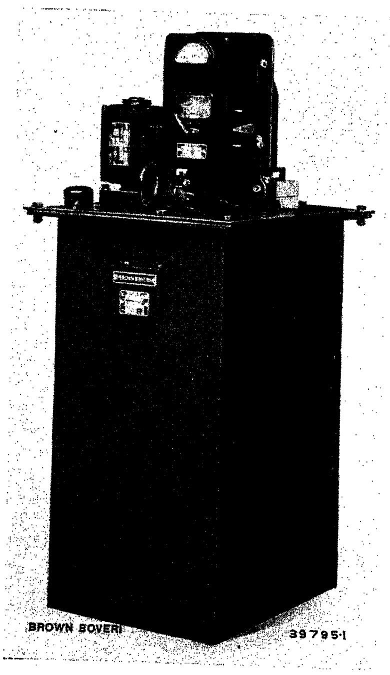


Fig. 61. — Three-phase low-voltage regulating transformer with built-on control relay and motor, 30 kVA carrying capacity, 380 V.

Rigid connections alone are used between the selectors and the sparking switch and there are no friction contacts on the shaft.

A detailed description was given in our last report of *transformers with continuous voltage regulation for low voltages.* The great advantages of those simple and cheap regulating transformers are increasingly appreciated by our clients.

We have enlarged the standard range of these transformers containing 3 sizes, covering an output range of 100÷500 kVA, by a new type for 30 kVA carrying capacity and 380 V, star-connected (Fig. 61). The design allows of building these transformers for other voltages up to 500 V. The carrying capacity varies in direct ratio and the regulating range in indirect ratio to the rated voltage. The regulating winding and current collector are designed for a rated current of 46 A. The total additional voltage of the regulating winding is 57 V at 380-V system voltage which corresponds to a total regulating range of 15 %. By connecting the regulating winding to a tap of the excitation winding, regulation in voltage-increasing and voltage-lowering sense can be attained (± 7·5 % at 380 V), instead of a regulating range in one sense only.

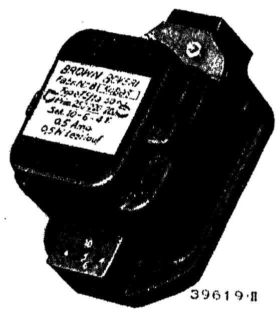


Fig. 62. — Single-phase air-cooled bell transformer 5 VA.

In special cases where the deformation of the voltage triangle as a result of asymmetrical loading is relatively big, which often happens in low-voltage systems with a neutral wire, our transformers with continuous regulation can be fitted with a compensating transformer, in the same tank.

When on this subject, mention should be made of the development of *bell transformers* (Fig. 62). The secondary no-load voltage is 10 V for both models available of 220 and 125 V primary voltage, respectively. A tapping allows of taking power at 4 and 6 V. The output is 5 VA at 10 V on the secondary side. These transformers are mechanically and thermally absolutely short-circuit proof in their housing of fire-proof insulating material.

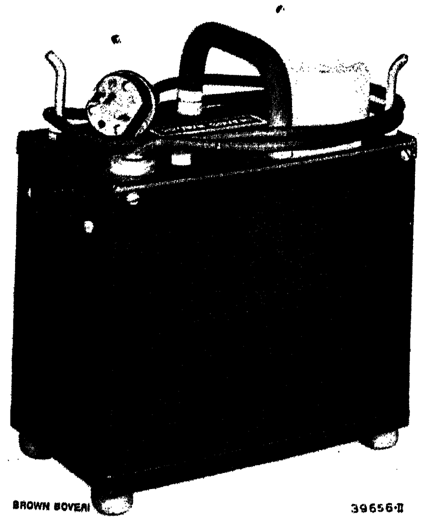


Fig. 63.— System-transition transformer, 750 kVA, 220/132 V, 50 cycles.

They can be delivered with the "passed" stamp of the Swiss Electrotechnical Society (SEV).

If the distribution voltage of a system is altered, as often happens when it is changed over to conform to some uniform standard voltage, small auxiliary transformers for single dwelling houses or buildings come in very useful, to allow of going on using, for the time being, existing electrical household utensils (electric heating cushions, irons, cookers, small motors, etc.). To this end, we have brought out what may be termed a *system-transition transformer* (Fig. 63). These units are built for single-phase service up to a max. of 500 V and an output of up to 3000 VA at 50 cycles and for any usual voltage asked for. The designs conform to the SEV regulations.

Finally, mention should be made, here, of a new *oil-testing apparatus* to take the place of the former portable testing apparatus with induction regulator and testing transformer up to 50 kV. The new apparatus consists of a testing transformer of our well-known design with a high voltage of 70 kV, only the windings being oil-immersed. Voltage regulation is from the primary side through series resistance. The whole portable apparatus is neat and compact.

B. DISTRIBUTION-SYSTEM PROTECTION.

In the field of distribution-system protection, we would refer to our *dissonance extinguishing coils* which were developed some years ago, to compensate the capacitive earthing current and which met with such success. Last year, we had occasion to build a large number of these for indoor and outdoor erection. Of these units, two coils for 1000 and 665 kVA intended for an extensive 20-kV overhead system are especially interesting:— the system was run with straight earthed neutral and was protected against short circuits by distance relays in all three phases. With this system of distance protection, there were many difficulties encountered in service. Various tests showed that these difficulties were due to insufficient earthing. As, owing to the cost entailed, there could be no question of improving the earthing, we advised the authorities to earth through extinguishing coils and the result was that, once the coils were put in, all cases of trouble were cleared by the distance protective equipment.

Among the extinguishing coils delivered, there are a number having secondary windings; we would mention two coils with a two-hour output rating of 1100 kVA, the secondary winding of which was built for a three-minute output rating of 1350 kW. These coils were delivered to the 77-kV system of the Krangede Co., Stockholm. Another coil has a two-hour output rating of 2700 kVA and a secondary winding for a ten-seconds output rating of 500 kW; it is used to protect the 70-kV system of the Forces Motrices du Haut-Rhin. The biggest extinguishing coil built by us, so far, has a two-hour output rating of 5500 kVA and was delivered to the Kungl. Vattenfallstyrelsen in Stockholm.

The advantages of earthing compensation by means of extinguishing coils is especially marked when it permits the operators to determine the defective line section quickly and without any trouble, when the earthing is a continuous one. To this end, we placed our *earthing relay* (Fig. 64) on several systems. These are sensitive wattmetric directional relays connected to current transformers in Holmgreen (totalizing) connection and to voltage transformers between the neutral point and the earth. With those connections, we measure the direction of the zero sequence component of the watt current flowing through the line. According to whether this output is flowing to or away from the relay, the moving system of the relay moves is one sense or the other. The sense of displacement is recorded by a simple indicating device. The indication or, rather, the indications of the various relays offer an easy way of determining the defective line section. Fig. 65 gives three examples, which require no explanation.

In most cases, however, the watt load is too small to make the re-

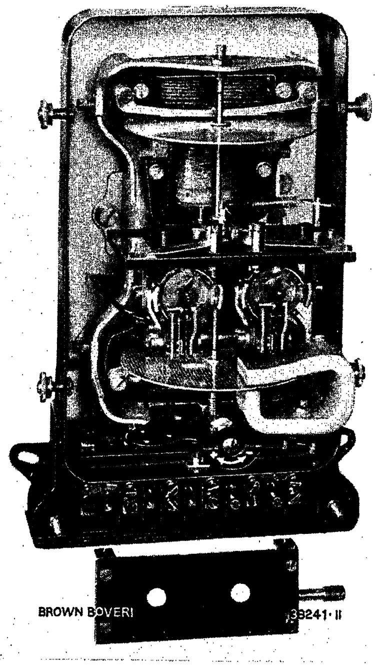


Fig. 64. — Earthing relay. Cover removed.

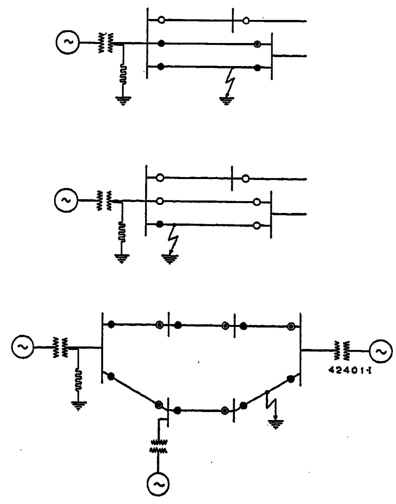


Fig. 65. — Examples to show the detection of an earth fault by the earthing relay.

lays act or else so small that the inherent measurement-transformer errors falsify the indication of direction. It is, thus, advantageous to increase the watt current, this by inserting an ohmic resistance for a short time between the neutral point of the system and the earth. When high voltages are in question, the resistance is connected to a secondary winding of the extinguishing coil instead of being direct-connected to the system.

A new relay, termed *ratio differential relay Type T* has been developed to protect transformers from inner defects and terminal shorts.

Apart from the influence of the magnetizing current, there are several causes, in the differential protection of transformers, which go to form differential currents, and these may cause the said currents to develop even when there is no trouble in service. The first of these causes is the variability of the voltage ratio in transformers equipped with tap-changers or having on-load tap regulation. Although it is possible to prevent the influence of such differential currents from affecting the relays by equipping the current transformers with suitable taps and then by making a corresponding change in the ratio of the latter whenever a change in the ratio of the main unit is effected, compensation of this kind leads to complicated solutions. Further, differential currents can arise by deviations in the ratio of the rated currents of the measurement transformers on the high-voltage and on the low-voltage sides such that the ratio does not exactly correspond to the ratio of the transformer to be protected. Such deviations are frequent, because in chosing the rated currents of the measurement transformers the normal range stepping has to be observed and there also are differences in the characteristics of the measurement transformers on the high-voltage and low-voltage side, explained by the difference in design of the measurement transformers, due to the big voltages or big currents they are built to stand up to.

The new ratio differential relay allows an adaptation of the differential protection to transformers with two and more windings and taking special account of the factors first enumerated. The relay has two coupled systems opposed to one another: — the holding coil and the tripping coil. The holding coil takes the carrying-capacity current (rated load current or short-circuit current) while the tripping coil takes the difference current (due to a fault or magnetization). This design of relay allows of it working with a pick-up current which varies instead of being constant. This pick-up current is all the bigger, the bigger the carrying-capacity current, so that in the case of short circuits outside the protective range of the relay, there is no tripping, this despite the fact that the difference current has grown with the carrying capacity current. The ratio between pick-up current and carrying capacity current, the so-called "pick-up ratio" can be set on the relay in steps of 10—50 %. The influence of the magnetizing current is compensated by the mechanical counter torque of a spring. The design of the relay also allows of a setting of the latter compensation in a range of 20—40 %. Faulty trippings which may result from the closing current which flows when the breaker is closed, are prevented by an auxiliary relay with additional time lag, in the tripping circuit.

The relay is built to be connected to current transformers stepping down to 5 or to 1 A. However, the relay coils can be wound for 1, 1·73, 5 and 8·7 A and, accordingly, allow the relay to be used with star or delta-connected current transformers. The power input is especially low, being only 1 VA for the holding coil and 4 VA for the tripping coil, referred to rated current. Fig. 66 shows a three-pole design of the ratio differential relay. An auxiliary relay with two-pole releasing contact and signal trap is direct-mounted on the middle differential relay.

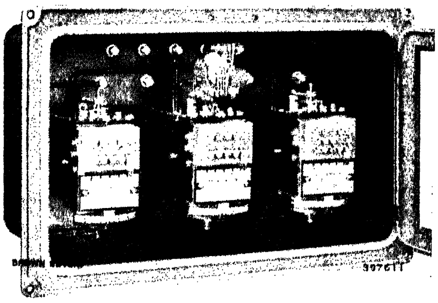


Fig. 66. — Ratio differential relay in three-pole design.

The newly-developed *lightning arrestor Type HF* for service voltages up to 40 kV, which were described in our last year's report, have found a wide field of application. The reports of service results with these arrestors during last year's stormy period are very satisfactory. The exceedingly rapid ignition time of this arrestor which is 1/10 μs at the maximum is much appreciated, as well as the big drop in voltage which is a result of Resorbit resistance being dependent on the voltage across it (see characteristics Fig. 67).

In order to meet the demand for effective protection against over-voltages due to storms for low-voltage systems, in so far as they are laid out as overhead-wire systems, we have placed a very practical arrestor on the market for D. C. and A. C. voltages up to 500 V (Fig. 68). The remarkable voltage drop caused by this arrestor is shown clearly in the cathode oscillogram Fig. 69.

It should be said, here, that the Resorbit arrestor allows of correcting at the entry of the line into the

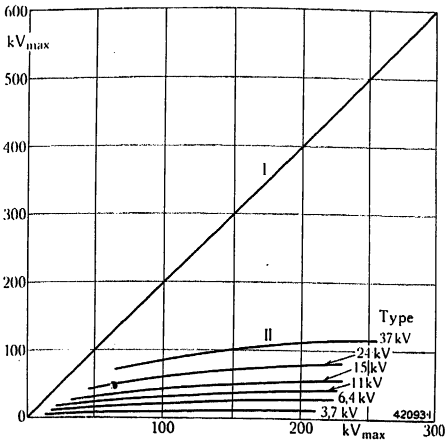


Fig. 67. — Characteristics of Resorbit lightning arrestors for 3·7 to 37 kV.

Abscissae: Amplitude of incoming current surge.
Ordinates: Voltage in terminal station.
I. Without arrestor.
II. With Resorbit arrestors.

plant the insufficiently graduated insulation which characterizes many plants. The Resorbit arrestors act under such a moderate voltage and reduce the impulse voltage so effectively that flash overs are prevented even in very poorly insulated plants. The protective effect is shown by Fig. 70. The cathode-ray oscillogram a shows the negative impulse wave A, above, of 195 kV on a well insulated line which stands up to this stressing without flashing over. If, now, an 11-kV supporting insulator is connected up to the line, it flashes over at 156 kV. If a Resorbit arrestor for 11 kV rated voltage is, now, connected in parallel to the insulator, the arrestor acts at 46·5 kV and the residual voltage is about 40 kV. The supporting insulator, however, can well stand up to this stressing without flashing over. The two oscillograms, b and c, show what a big factor of safety has now been introduced; these oscillograms show that even the supporting insulators for 6·4 kV and for 3·7 kV service voltage have a considerably higher flash-over voltage (140 kV and 120 kV) than the ignition voltage of the 11-kV arrestor. Even these low-voltage insulators will no longer flash over after the arrestor has been connected up.

Finally, while on this subject, mention should be made of our *electrostatic synchronising device* for high-voltage plants in which terminals, upright or suspension insulators, acting as condensers, serve as a source of voltage. An electro-static synchronoscope of the Sieber system (Fig. 71) serves as indicating instrument; it is equipped with a light pointer. The source of light is a 30-W incandescent lamp fed, at 6 V, by a small lighting transformer.

C. THE COUPLING OF SYSTEMS.

In the field of system coupling we would mention an order received for an induction-synchronous converter set with Scherbius set for the *Bevers Substation of the Rhätische Werke für Elektrizität in Thusis.*

This converter set is to replace a three-phase-single-phase converter with flywheel and storage battery. On the A. C. side it will be either supplied from the power stations of the Brusio Co. in Puschlav or from the Rhätische Werke in Thusis; it works, on the single-phase A. C. side, in parallel with the single-phase generators of the Rhätische Werke in Thusis or the Bündner Kraftwerke in Küblis on the contact wire of the Rhætic Railway. The set, thus, serves as a flexible connection between two systems the frequencies of which fluctuate from 49·5 to 51·5 cycles and 15 to 18 cycles respectively. The converter set is to be in continuous buffer duty. The output on the shaft of the single-phase generator, which was taken over from the old set, amounts to 1300 kW continuous rating or 2000 kW five-minutes rating.

Fig. 68. — Single-pole lightning arrestor for low-voltage systems.

A new element in the plant is the newly-designed *frequency regulator* to be used to govern the load trans-

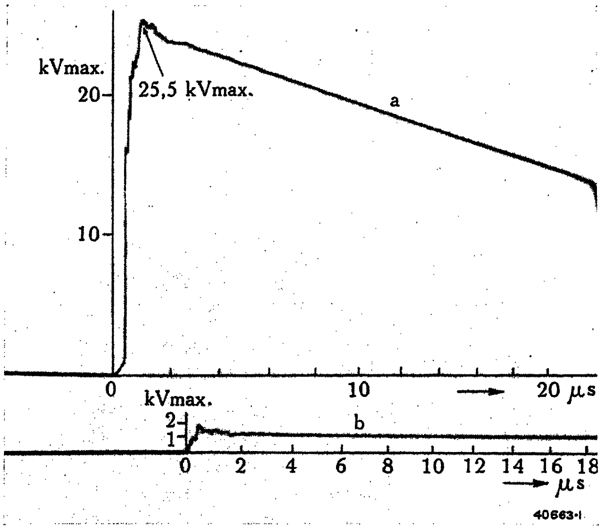


Fig. 69. — Cathode-ray oscillogram of the drop in a voltage wave brought about by a lightning arrestor, according to Fig. 68.

a. Incoming original wave of a crest value of 25,000 V.
b. The same wave after being reduced to the residual voltage of about 1000 V.

mitted in function of the frequency on the railway line, it takes the place of the former standard turbine pendulum.

This order brings up to 11 the number of converter plants delivered by us for the flexible coupling of systems. Fig. 72 gives recent record strips of the Seebach converter set of the Swiss Federal Railways. They show that, after four years of service since taking over, during which period the single-phase generator was nearly always fully loaded, the precision of regulation has remained as good as ever. It may be added that as regards the machines of the Scherbius set all that was necessary, during the last two years, was a single change of all the brushes.

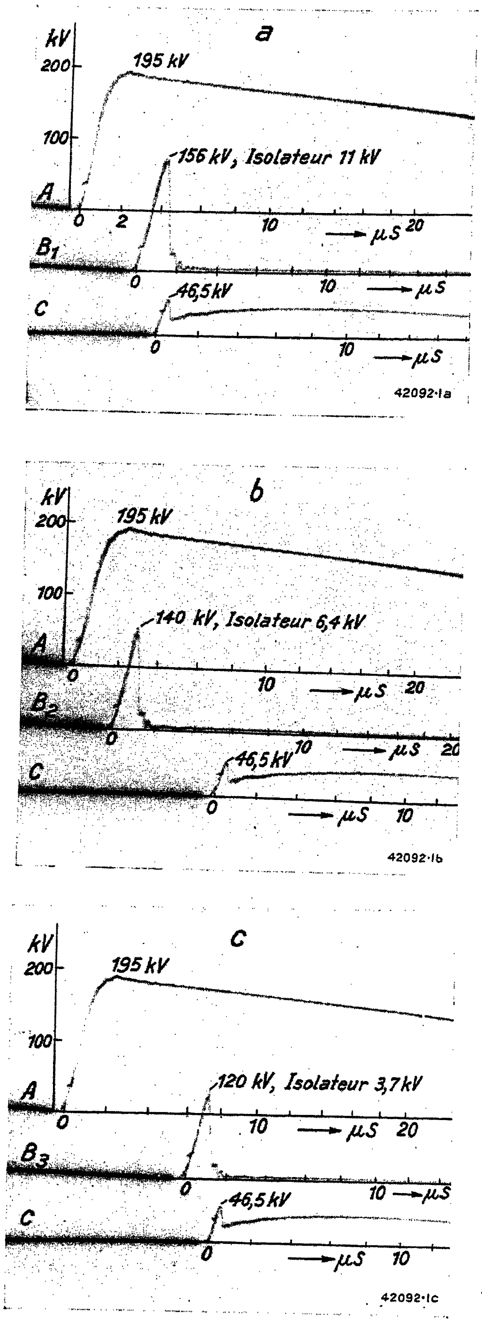


Fig. 70. — Protective effect of an 11-kV Resorbit lightning arrestor.
a. Protection of 11-kV insulator.
b. Protection of a 6·4-kV insulator.
c. Protection of a 3·7-kV insulator.
A. The impulse wave reflected at the end of the experimental line.
B_1 B_2 B_3. Flash-overs on the 11, 6·4, 3·7 kV upright insulators, respectively.
C. The impulse wave reduced by the arrestor.

The average daily efficiency measured over a period of a fortnight on the Mühleberg converter plant of the Bernische Kraftwerke, Berne shows that the figure attained is remarkably high even with the fluctuating load dealt with in railway service. With 40,000 to 100,000 kWh per day delivered on the single-phase side which corresponds to an average output of the single-phase machine of about 26 to 65 % of the rated load, the average daily efficiency shows a minimum of 72·3 % and up to of 92·6 %.

At the same time, intensive study was devoted to the solution of the problem of the *flexible coupling of A. C. systems* of different frequencies and of the same or of different number of phases, through the agency of *mutators*. A system of connections was worked out which allowed of flexibly coupling two three-phase systems of different frequencies by means of *a single mutator unit* (Fig. 73), a task which finds an application in Italy, for example, in the coupling of the three-phase traction system of low frequency and the industrial systems of ordinary frequency; up till now, this problem was successfully solved by using converter sets with Scherbius sets and frequency changers. Further, we had occasion of applying the system of connections developed by us for the coupling of a three-phase industrial system of ordinary frequency to a single-phase railway system of specially low frequency, using, again, only one mutator and also condensers for power storage. This was a plant ordered from one of our concessionary companies with a passed power of 4300 kVA and 110 kV on both sides. It will, therefore, soon be possible to get reliable data on this difficult but important side of the application of mutators, which holds the promise of great development.

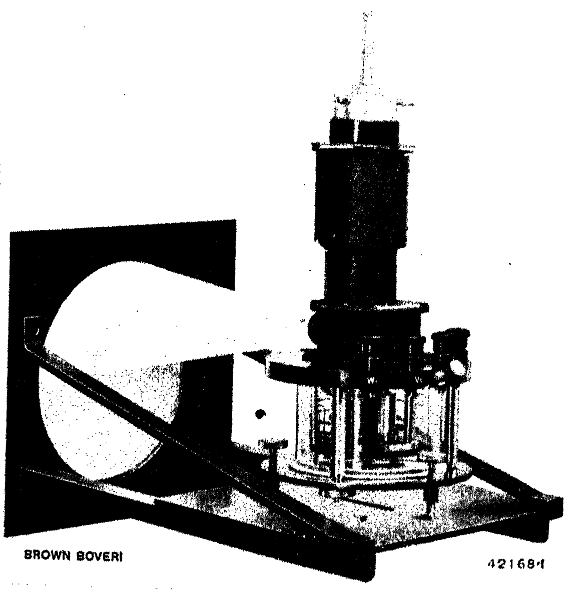


Fig. 71. — Electrostatic synchronizing device for high-voltage plants.

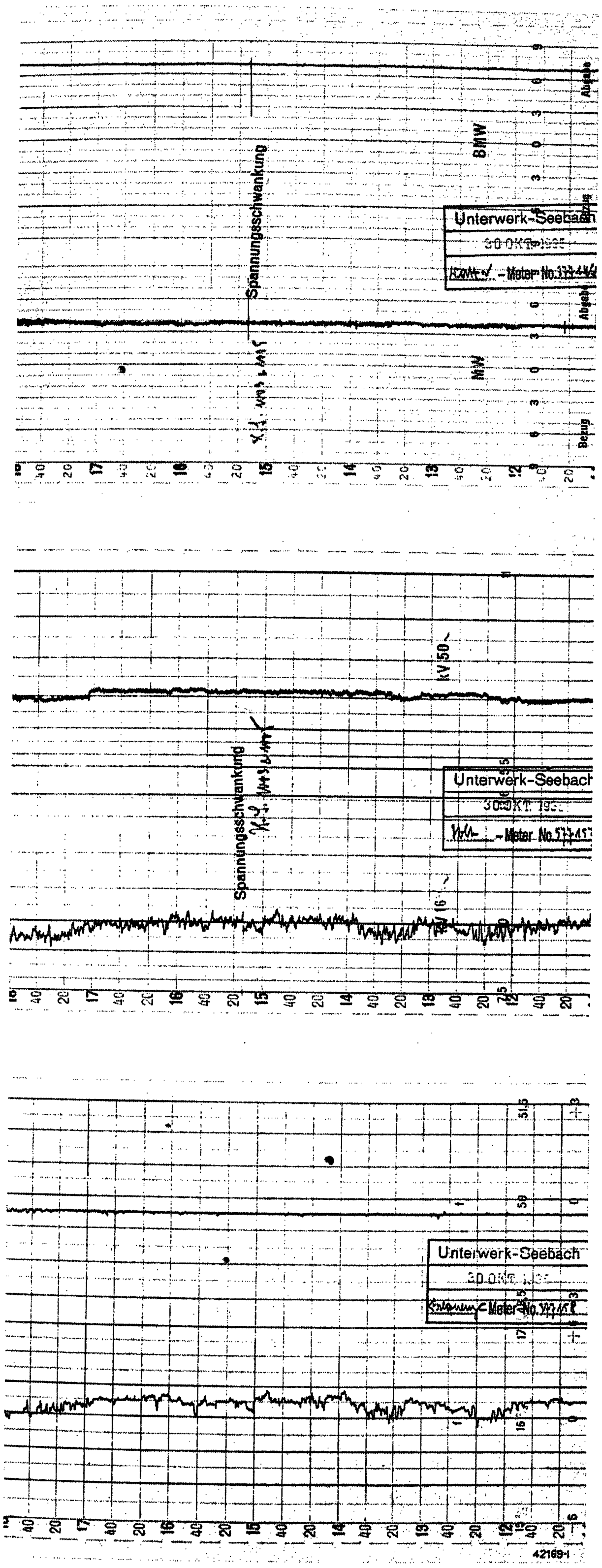


Fig. 72. — Recording paper strips of the frequency-converting set in the Seebach substation, Swiss Federal Railways.

a. Output from or to the industrial system.
b. Output from or to the railway system.
c. Voltage of industrial system.
d. Voltage of railway system.
e. Frequency of industrial system.
f. Frequency of railway system.

The van Reenen and Colworth Halt substations mentioned in our last report, supplying the South African Railways, are another application of system coupling. These stations were started up at the beginning of last year. It should be repeated here[1] that these are the first D. C. railway substations in the world having mutators for power recuperation through regenerative braking: these substations gave an excellent account of themselves from the day they were passed for service. Figs. 74 and 75 show two load diagrams of the van Reenen Substation.

D. MUTATORS.

In building steel tank mutators, the tendency has been the same as in other electric machinery, namely to fulfil the primary requirements of practice and to increase the outputs and currents delivered per unit; this development has come to a pause for the present and since the conversion problems which can be successfully solved by mutators and the question of the generation of much higher D. C. voltages have come to the fore. A natural result of the first mentioned tendency was the pushing of the output of glass-bulb mutators to the extreme and until currents of about 400 A were attained. Despite this, we were constantly meeting with requests from the circle of our clients for a mutator with steel tank for currents of about 250—400 A. The reason for this demand is to be sought in the fragility of the glass-bulb mutator and the fact that the latter ages quickly owing to deterioration of vacuum, which is translated into bigger losses. For these reasons the glass-bulb mutator is, relatively, more expensive to operate. The steel-tank mutator has, on the contrary, an unlimited life, thanks to the vacuum-pump set, which need only be run from time to time.

We began by developing a *small mutator* for a current range of 170—400 A (Fig. 76, left), for voltages of 1500—250 V which, in conformity with its size, had a number of simplifications in design as compared to our other bigger types. Among these simplifications, we would mention the elimination of water cooling here replaced by forced air-draught cooling delivered from a propeller-type fan lodged under the mutator. The tank proper has no cooling dome, has an enlarged cooling surface and is surrounded by a metal-sheet shield to guide the air. The high-vacuum pump is, also, air-cooled, it has cooling ribs on the outside and is placed just below the main tank and above the fan wheel.

This new small type of mutator should be popular for small transmitting stations.

We have successfully pursued our tests on the *high-voltage mutator*. Not only was the high-voltage

[1] See The Brown Boveri, 1935, No. 7, page 142.

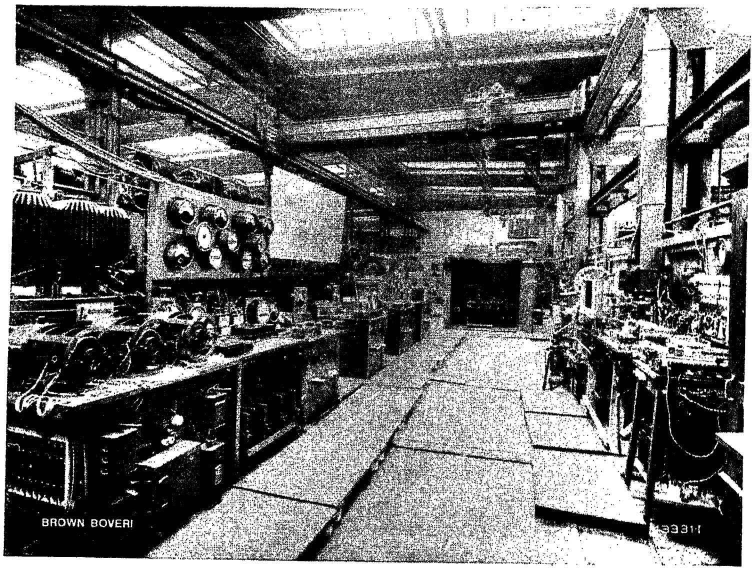


Fig. 73. — Part view of the mutator testing plant.
Plant to test AC-AC mutators and their control equipment.

raised until it reached 60 kV but two of these mutators were so connected that one acted as an A. C.—D. C. mutator and the other as a power receiver that is as a D. C.—A. C. mutator, so that a D. C. high-voltage transmission system was created, for the first time, using 50-kV mutators and developing about 1200 kW. We will refer to this plant, in more detail, in a subsequent number (Fig. 76).

A series of big mutators were delivered by us and by our concessionary companies for the three main fields of mutator industrial application: — electro-chemical plants with steel works, traction plants and wireless-transmitting plants. Special interest attaches to plants already equipped with our mutators and which put in repeat orders, thus furnishing further proof of the quality of Brown Boveri mutators. Among these, we would mention delivery of two further double mutator sets, giving together 20,000 A at 740—830 V, which will be added to the five double units already installed and giving a total of 50,000 A in the far-northern Canadian plant of *The Consolidated Mining and Smelting Company of Canada;* two mutators for a total of 10,000 A at 600 V for the *Porto Marghera* plant of the *Soc. Alluminio Veneto Anonima.* This plant already has six similar units working and delivering a total of 25,500 A. One of our concessionaries booked an order for 8 mutator units to give a total of 44,000 A at 600 V and to be lodged in a plant belonging to the same concern and which was operated with rotary machinery up to a recent date. This brings the total number of mutator units delivered to this one aluminium-electrolytic concern up to 20 delivering a total 97,500 A. Special mention should be made of the 24 mutator sets delivered to the *Southern Railway, England,* for their D. C. traction system. These units are each of 3800 A at 660 V. This brings up to 66 the total number of mutators delivered by us or built to Brown Boveri designs for the Southern Railway by Messrs. Bruce Peebles of Edinburgh; the total mutator output being 165,000 kW.

Further, we and our concessionaries have built:— two mutators for each 4800 A, 520 V, for the *S. A. des Laminoirs, Hauts Fourneaux, Forges, Fonderies et Usines de la Providence à Hautmont,* three mutators for 835 A, 1200 V, for the *Napoli-Vola-Baiano Railway* of the *Soc. Strade Ferrate Secondarie Meridionali, Napoli,* and two sets each of 670 A, 3000 V for the *Portichetto Substation* of the *Soc. Ferrovie Nord-Milano.*

As regards mutators for broadcasting stations, some interesting units were delivered, last year, among them:— a 450 kW, 17,500—18,500 V unit for the *Sottens* plant belonging to the Swiss General Telegraph Office in Berne; three units each of 1000 kW at 20,000 V to the *Ente Nazionale Audizioni Radiofoniche, Torino,* placed in the

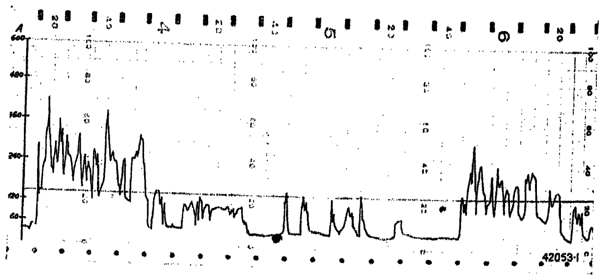


Fig. 74. — **Load diagram of the DC-AC mutator in the van Reenen Substation (South Africa).**

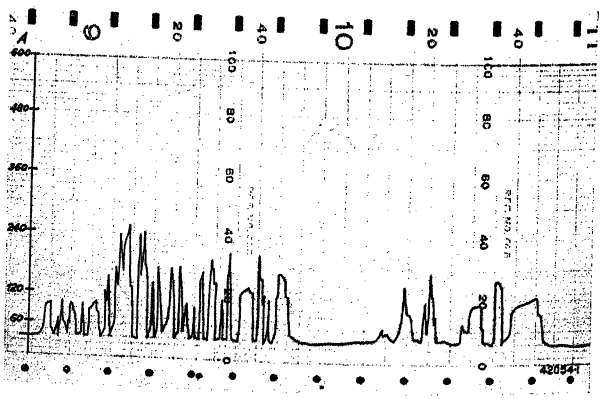


Fig. 75. — **Load diagram of the DC-AC mutator, in the van Reenen substation, when taking up a part of the power regenerated by a shunting train.**

Rome-S. Palomba broadcasting station; a unit of 180 kW at 20,000 V for the *Bologna* broadcasting plant, etc.

Among apparatus specially used in mutator plants the following new ones are worthy of mention: — a *small high-speed circuit breaker* shown in Fig. 77 built for a rated voltage of 1500 V and a rated current of max. 1000 A; this breaker is used wherever our breaker Type JC cannot be put in, on account of price and lack of space. The new small high-speed

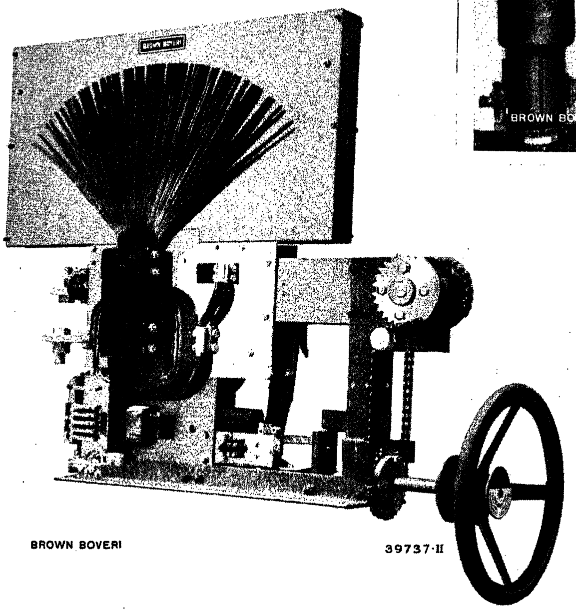


Fig. 77. — High-speed circuit breaker, rated voltage 1500 V, rated current 1000 A.

breaker is built for hand control or motor control and is especially suitable for putting in small and average-sized railway substations with rated voltages of 800 V to 1500 V. When directly hand-controlled, the breaker is mounted behind the switch-panel and the front of the panel only shows the handwheel with switching-

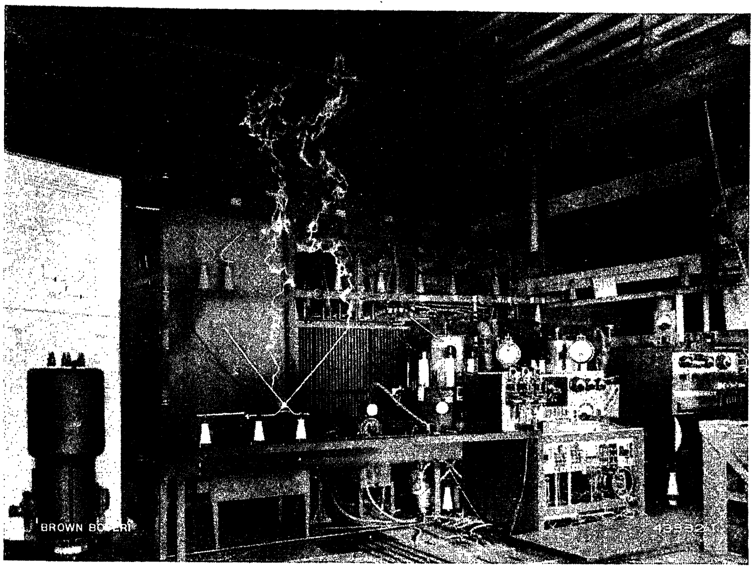


Fig. 76. — Testing plant to study power transmission by high-voltage D.C.

Demonstration of a high-voltage mutator working at 50,000 V D.C. and 30 A arc current. The arc current is extinguishing because a new ignition is beginning below, between the horns.

On left:— a small mutator for 170 ÷ 400 A.

sense and breaker position indicating device. The motor control is composed of the driving motor, reduction gear, slip coupling and end-travel switches and is built straight on to the breaker. The breaker can be hand-controlled as well from the handwheel provided. For remote control from the control desk, a contact maker or control switch with return signalling device are used. This high-speed breaker has block contacts so dimensioned that a single pair of contacts allow of carrying out over 1000 heavy rupturing operations. When the sparking chamber is lifted, it is easy to get at the contacts for purposes of inspection. The high-speed breaker can be equipped with the following relays acting on the release catch and operating mechanically:— An over-current relay, a polarized over-current relay, a polarized reverse-current relay.

For voltages below 800 V the automatic breaker L is still used.

III. OUR PRODUCTS IN INDUSTRY, TRADE AND AGRICULTURE.

A. DRIVES BY ELECTRIC MOTORS.

The available range of Brown Boveri *standard, three-phase small motors* with squirrel-cage and slip-ring rotors has been enlarged by a terminal-box design built in a variety of forms (for pipe connection, for cable connection, with cable-end box, etc.)

Our small motors were improved by the introduction of the *cast aluminium winding* which is used in small squirrel-cage motors up to about 3 kW. The copper-bar winding employed heretofore for these rotors, brazed to the short-circuiting end rings (Fig. 78) has been replaced by this cast aluminium winding put into the rotor by a special process. This aluminium rotor winding is a guarantee of absolutely uniform manufacture. It has no soldered joints and is able to stand up to all mechanical and electric stressing. It has shown itself to be practically indestructable under the heavy vibrations inherent to some types of drive. The two fans, one on each side, are also

cast in one piece with the short-circuit rings and assure most efficient ventilation of the motor (Fig. 79).

The pure aluminium is heated up to the proper temperature in an electric melting furnace with automatic temperature control, it is then poured into a mould into which the rotor body

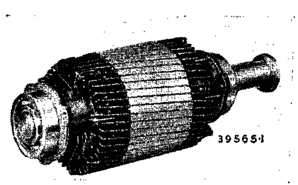


Fig. 78. — Squirrel cage rotor of old design.
(Rotor bars made of copper with brazed short-circuiting rings.)

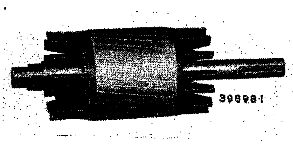


Fig. 79. — Squirrel-cage rotor with cast aluminium winding.

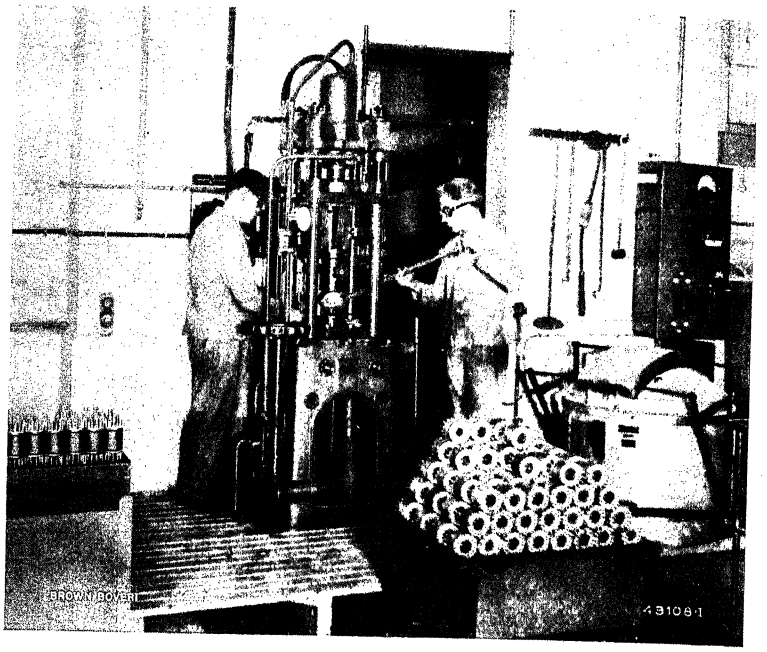


Fig. 80. — Manufacture of the aluminium rotor winding.
Electric furnace plant with casting machine. Pouring of the aluminium into the mould. In foreground:— cast aluminium rotors complete.

Fig. 81. — Exhibition of standard products in the machine-testing department, Brown Boveri & Co. Ltd., Baden.

has been pressed. Fig. 80 shows this process with the appropriate manufacturing plant, in our shops. The aluminium is sprayed under high pressure into the casting mould and, thus, into the laminated rotor body; it is then made to solidify under the influence of a considerably greater pressure. The high pressure results in absolutely homogeneous casting throughout every part of the rotor slots. This process is a big advance in the building of small motors when compared to the method in general use formerly.

In our last report, we mentioned the series of practically noiseless *single-phase motors with starting commutators,* built in a three-size range. This range has, now, been enlarged by two bigger types, so that it is represented to-day by five types from $\frac{1}{8}$ to $\frac{1}{2}$ H. P. and covers all practical requirements. These motors are being used, increasingly, for refrigerating cubicles, but are universally adaptable and useful for the drive of washing machines to which they are easily built on owing to the variety of design: — horizontal, vertical, with foot or flange, with journal or ball bearings. The two new types, just mentioned, appear to be especially suitable for washing machines and pumps.

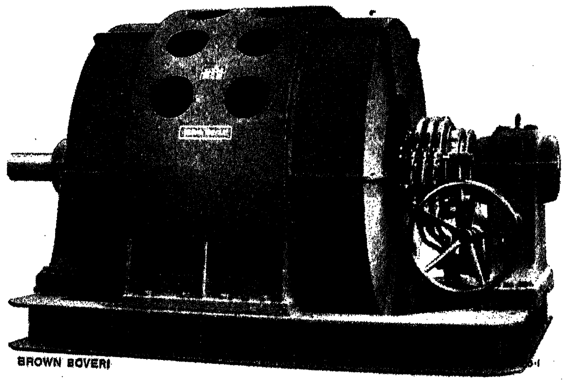


Fig. 82. — Three-phase A.C. motor Type MSp 305 spec. open design with housing, shields and bedplate of welded plates. Intended for drive of a compressor and reduction gear. Output 1720 kW at 1000 r. p. m., 6000 V, 50 cycles.

Fig. 81 shows a number of new designs in the field of small motors.

Welded-plate designs are beginning to take first place in the construction of the *bigger induction motors* (Fig. 82); the rotor as well as the external parts such as housing, shields, bedplate being all built up of welded plates. This construction makes the machine lighter, increases its rigidity and allows of providing for better cooling conditions, the last two advantages apply specially to the rotor. The cooling improvement has a certain importance as, under present keen competition, bigger outputs are leading to longer machines, with a consequently, greater length of active iron and, here, the problem of rotor ventilation tends to limit the development, especially in high-speed machines.

By using welded-plate construction and a new type of ventilation, it has now been found quite feasible to attain efficient coolings of all parts of the motor even with very long iron cores.

Among machines of this type delivered, we would mention:— one motor 1720 kW at 1000 r.p.m., 6000 V (Fig. 82), a similar unit for 2300 kW at 900 r.p.m., 6000 V and, finally, the driving motor of the system-coupling converter set for the Bevers Sub-station mentioned elsewhere, built for 1450 kW at 500 r.p.m., 500 V. A remarkable feature of this motor of big output and low voltage is the use of transposed bars, of our special design, in the stator winding.

The *three-phase shunt commutator motors* have been made the subject of much study, they will be described in some detail when we deal with *fields of utilization.*

Among the drives used in the *textile industry,* that of ring spinning frames by three-phase commutator motors is still the most interesting. The spinning regulator, developed in its main lines by us nearly 30 years ago and which regulates the motor, by brush displacement, automatically, to the most advantageous speed, is now built on to the motor so that it forms an organic whole with it (Fig. 83) instead of being placed separately between motor and machine driven.

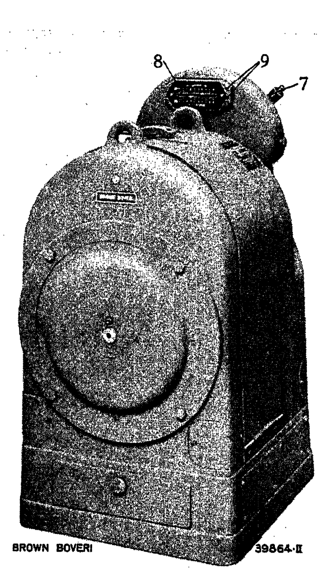


Fig. 83. — Three-phase shunt commutator motor Type PND 126.

7·5 kW, 1250 r.p.m., 600 to 1250 r.p.m., 50 cycles, with built-on spinning regulator; seen from the driving end.

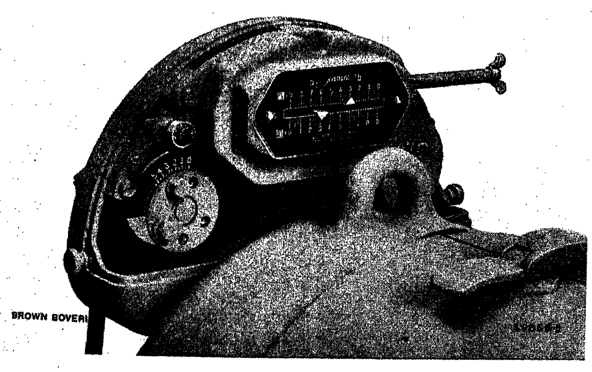


Fig. 84. — Spinning regulator type SN built on to the motor.
Shields removed.

All parts of the regulator are very accessible the basic cam and periodic cam are delivered ready for work and require no adjustment work done on them. There is a box key which allows of adjusting the basic cam and the periodic cam independently of each other and very easily, the regulator being closed and the settings being read off on a scale. The box key in question is also used for adjusting the spinning speed for cope-base formation, which speed is also read off from another scale. The three fundamental values for spinning regulation, namely:— speed for cope-base spinning, variation of basic speed and variation of periodic speed can, thus, be adjusted, with perfect ease, by means of a common key, to suit the spinning conditions to be met, while the scales provided allow of exact supervision of operations. The basic cam has additional cam pieces which allow of making a further adjustment of the spinning diagram for the basic speed during a whole doffing, namely permits of a modification of the time required to spin the cop base.

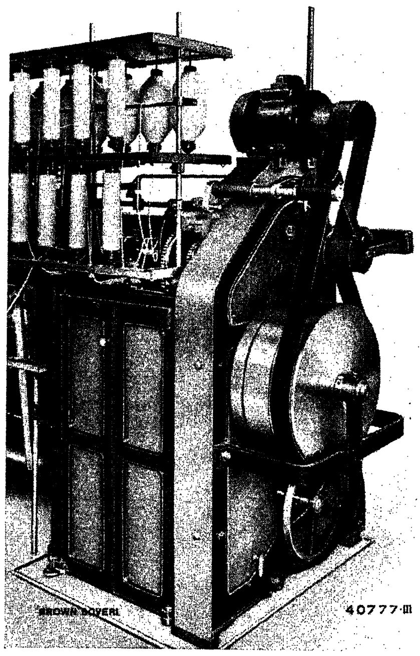


Fig. 85. — Drive of a flyer.

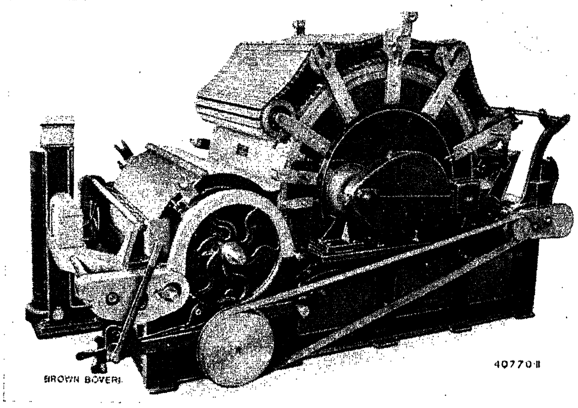


Fig. 86. — **Individual drive of cotton card by means of a totally enclosed loom motor.**

As the motor and regulator form a whole, there is a further saving in axial space so that full advantage can be taken of the small dimensions of our three-phase shunt commutator motors for spinning-mill drives.

Fig. 84 shows the regulator alone, with shield removed.

In *flyer drive,* the successful arrangement of placing the motor on the headstock and driving the flyer by belt over a jockey pulley has been adhered to. The iron bracket for the motor was modified to suit totally-enclosed motors with external cooling. It is impossible for dust to penetrate into these motors and supervision is reduced to a minimum. A switch box with motor protection by thermal release is built on to the bracket. The arrangement (Fig. 85) is characterized by compactness and easy operation; all service requirements are met by simple means.

By displacing the belt over to the fixed pulley, the flyer starts up smoothly; for threading, the flyers can be inched into the desired position by slight backward displacements of the belt, in the same way as in transmission-shafting drive.

Of the various other special drives built by us for all branches of the textile industry, some interesting equipments were delivered, in the past year, for *cotton cards.*

Space is often restricted in the card rooms of cotton mills. Fig. 86 shows a suitable compact arrangement of a card for cotton. A totally-enclosed loom motor with high starting torque is lodged in the frame of the card machine and drives the main shaft of the latter through a roller chain. The motor-protection switch box with thermal release is also secured to the frame of the card machine. The shaft end of the motor which projects beyond the gear is used to carry a small cable pulley to drive the stripping brush and is usually covered by a protective hood. We delivered a large number of drives of this kind to a new cotton mill in Rumania, among others.

In our last report, we mentioned a new regulator which we had brought out to keep the working speed of the *sectional drive of paper-making machines* exactly constant; this regulator has now been so modified that it can be used for drives having a wide range of regulation. It has given excellent results in several industrial plants. Apart from the great precision of regulation, the operatives much appreciate the absolutely smooth setting (without steps) of the working speed. This setting is carried out by rotating a three-phase choke coil, built into a switching cubicle along with the instruments required to supervise the whole drive (Fig. 87).

For drives of this kind, special starting processes combined with completely-automatic push-button control have been perfected for the starting up of the various sections. With non-stop day and night running of paper-making machines, the motors are started up relatively rarely, so that a common starting equipment can be used for all the sets to be started, for the sake of economy. The equipment brought out by Brown Boveri, adjusts itself automatically to the motors of different outputs, to the various starting and accelerating torques as well as to the starting times called for. Further, push-button control allows of setting low working speeds such as are required for certain secondary duties. The equipment in question can be designed either for using with resistances or for special

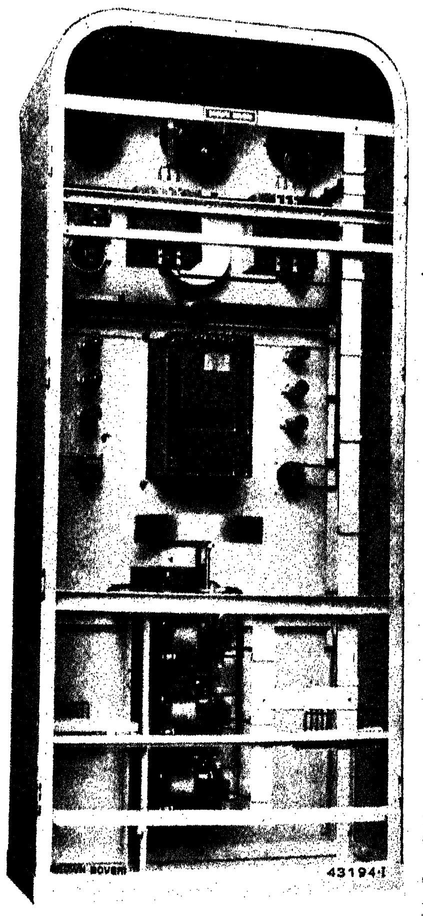


Fig. 87. — **Switching cubicle for electric regulation of speed of manufacture in a paper-making machine.** Seen from the back.

starting generators or for a combination of both. An equipment of the latter type was delivered to the *Papierfabrik Ignaz Spiro & Söhne A.-G., Bömisch-Krumau,* and has given great satisfaction.

A so-called *electro-winder* has been developed for the paper industry and delivered for driving winding-up devices in paper-making and damp machines. It is composed of a motor with reduction gear the speed of which is regulated by a special automatic device, in such a way that although the diameter of the roll of paper grows, the tension under which it is being rolled up remains constant. It should be mentioned here that drives of this kind and the automatic control gear required for them were specified by us as early as the year 1913 (DRP 293743), but did not find any extensive application until the sectional drive of paper-making machines — that is the intensified sub-division of drive — had begun to be extensively used. The properties described in the aforesaid patent have become common property to-day.

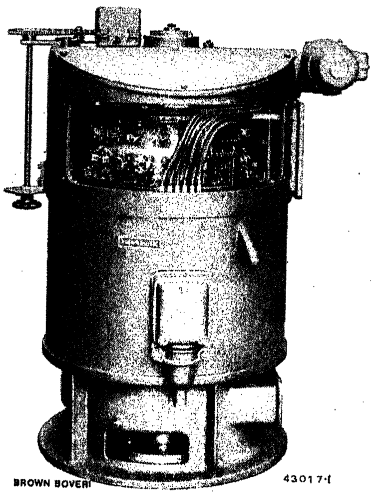


Fig. 88. — Three-phase shunt commutator motor Type PNDVa 256 spec., 37/12 kW, 1420/470 r. p. m., 230 V, 50 cycles, for sugar centrifugal drive.

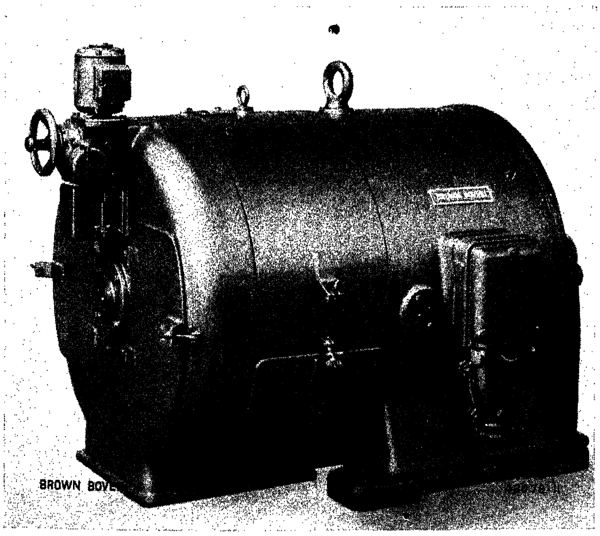


Fig. 89. — Three-phase shunt commutator motor Type PNDa 268, 50/14 kW, 960/620 r. p. m., 220 V, 50 cycles.

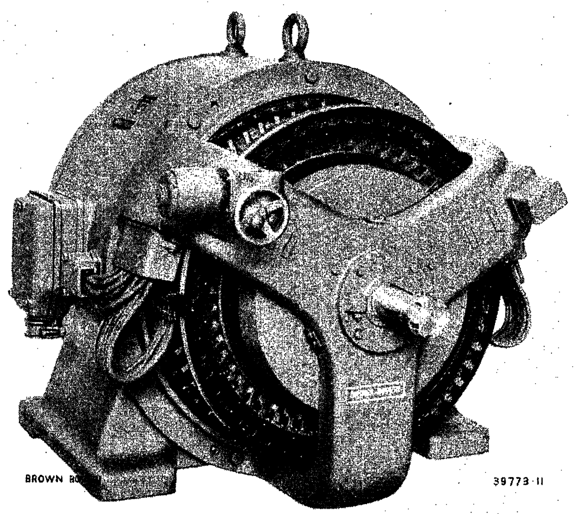


Fig. 90. — Three-phase shunt commutator motor Type PNa 2912, 140/48 kW, 680/235 r. p. m., 550 V, 50 cycles, for the drive of a calender.

Our last report touched on the ever-increasing field of application open to *three-phase shunt commutator motors.* These motors are being increasingly used in all kinds of drives in which smooth speed regulation without loss is required or desired (Figs. 88 to 92).

Fig. 91 shows the drive of a *rotary furnace* (cement industry) by means of a shunt commutator motor of totally enclosed design with forced ventilation; this motor is controlled by push-buttons from the furnace operating stand. The operation of the furnace benefits greatly from the simplicity of control

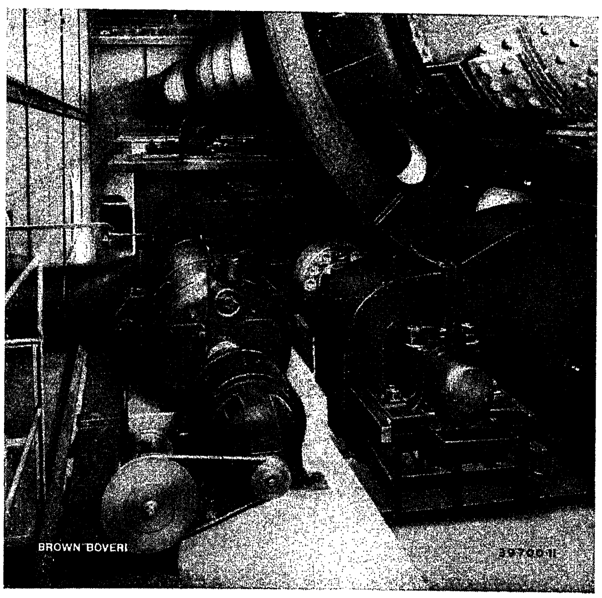


Fig. 91. — Drive of a rotary furnace by a three-phase shunt commutator motor of totally enclosed design with pipe ventilation. Type PND 266, 48 kW, 1250 r. p. m., speed variable down to 625 r. p. m., with fan, contactor cubicle, reduction gear, 1250/24·8 r. p. m., and auxiliary D. C. dynamo.

and the smooth speed variation on a wide range and independent of possible variations of the torque. An auxiliary dynamo is coupled to the motor which supplies power to the motor which feeds the rotary furnace with raw material. This system — patented by us — has the advantage of regulating the amount of feed to the furnace, according to the speed of rotation of the latter.

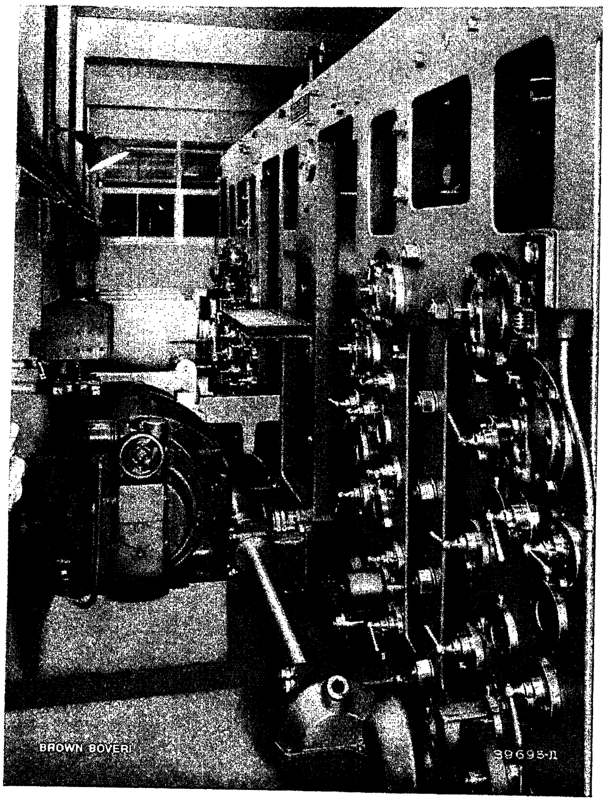


Fig. 92. — Drive of a simple rotary machine by means of a variable speed Brown Boveri three-phase shunt commutator motor Type PNR 256, with entirely automatic control.

The drive of *double and multiple rotary* machines by shunt commutator motors (Fig. 92) in which these motors and the driving organs of the said machines are rigidly coupled together, as is customary in such cases, are equipped by us with a special device which distributes the total load evenly and automatically over all the driving motors. Shunt commutator motors with suitably designed control equipment and regulating devices for the maintenance of constant relative speed can be used for the drive of sectional paper-making machines. These motors are chiefly suitable to high-speed newsprint paper machines in which the saving effected by the elimination of the ordinary A.C.-D.C. converting equipment is of some importance.

The Brown Boveri Review gave details of new drives evolved for the *rubber industry*[1]. We would only refer here to the motor equipments delivered last year to the *Firestone-Products plant* in *Pratteln* (Switzerland). These equipments met a variety of very interesting technical conditions as regards controlling, regulating and braking, into the details of which we will not go, here; we would only mention the very effective and purely electric braking of the big motors for the drive of the rubber calenders.

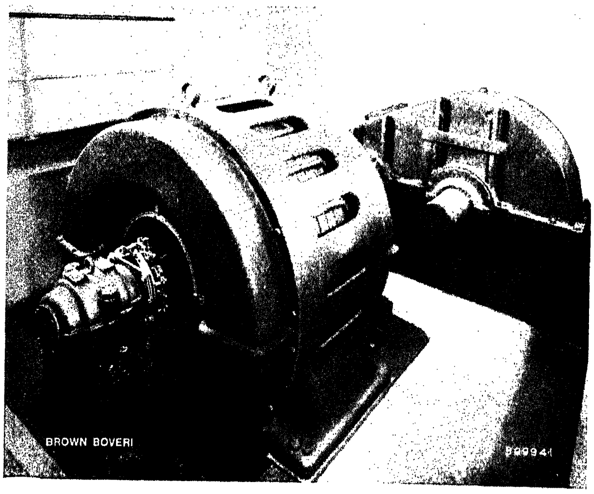


Fig. 93. — Drive of a set of five 84″ rubber rollers by means of a three-phase synchronous motor 440 kW, 3400 V, 600 r. p. m., equipped with helical gear wheel drive, 600/100 r. p. m.

In case of danger, as for example, if a workman's hand has got drawn into the rollers, very severe conditions were imposed as to stopping, for the sake of the operator's safety. A slight pressure exerted on the safety bar mounted in front of the calender had to suffice to bring the machine to a practically instantaneous stop. Thus, a synchronous motor of 440 kW at 600 r.p.m. (Fig. 93) had to be braked to a stop within 5 revolutions reckoned from the moment the safety rod has been actuated.

It was even found possible to design the motor and control gear so that this emergency braking takes less than $4\,^1/_2$ revolutions. Three squirrel-cage motors of each 110 kW af 980 r. p. m. were put in which

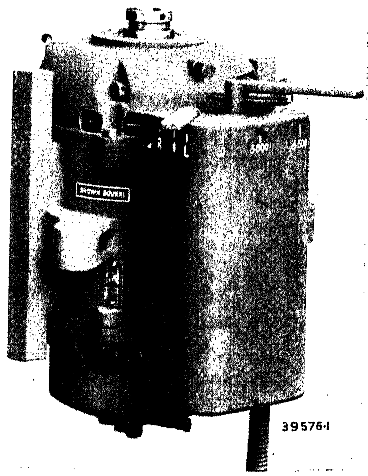


Fig. 94. — Double motor for the drive of moulding cutters and millers. Output 3 kW, 3000—4500—6000 r. p. m., 380 V, 50 cycles with special built-on switch for reversing sense of rotation, and switching the motor on to all three speeds.

[1] See The Brown Boveri Review, 1935, No. 11, page 218.

could be braked to a standstill in about 7 revolutions only, instead of the 10 specified for, this by means of counter current.

In our second-last report, we gave some notes on our *machine-tool motors* specially designed for the *wood-working industry,* and mentioning the double motor used for the drive of moulding cutters and millers which allowed of setting the three speeds 6000, 4500, and 3000 r.p.m. Fig. 94 shows one of these motors with built-on controller which allows of starting, braking and changing-over the motor in the easiest possible way. Apart from the simple design of the motor allowing of easy supervision, there is an interesting blocking device which prevents switching on further, to 4500 or 6000r.p.m. when working with a slot cutter for 3000 r.p.m. This fulfills a very essential condition for the operation of moulding cutters and machines equipped with these motors can be entrusted to any workman.

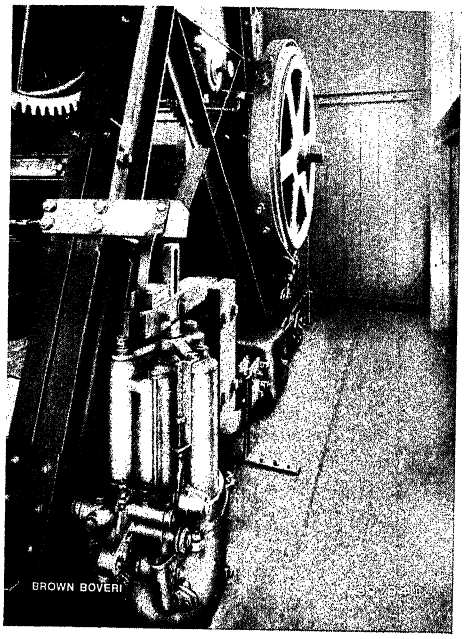


Fig. 95. — Electro-hydraulic thrustor as a brake-raising device built into the winding gear of a powerful loading crane with many switchings per hour.

In the field of the drives of *hoisting and conveying equipments* we would mention, again the *electro-hydraulic thrustor* touched on, here, last year. Fig. 95 shows one of these, built into the winding gear of a powerful loading crane and acting as a brake-raising device. This apparatus gave an excellent account of itself under very severe service conditions, comprising 600 switchings per hour. The adjustable drop-weight damping characteristic is especially welcome as it spares both brakes and the whole winding gear.

Among the important orders taken by us or our concessionaries for winding plants, we would mention the following ones:—

The making over of an existing steam hoisting equipment with a bi-cylindro-conical drum of 2·6/3·7 m diameter built for hoisting a 1300 kg net load from a max. depth of 325 m at a speed of 11 m per second. In order to make use of the existing shaft and to use the steam engine as a spare, a D.C. motor was placed on each side of the drum and the latter driven through reduction gears with the ratio of $^1/_{10}$; the two crank discs being so transformed into couplings that the machine can be changed over to steam-engine drive at any time. The dynamo of a converter set supplies both motors, there being a switching-over device to allow of only one motor being supplied, if so desired. This plant was for the *Sté Française des Pyrites de Huelva.* We delivered the complete control, braking and safety apparatus for the electric equipment of an existing mine hoist for raising a net load of 1200 kg at a speed of 3 m per second from a depth of 180 m. An interesting feature is the use made of our single-lever controlling and braking equipment with which an oil counter-pressure regulating brake, mentioned in our last report, is used for the first time in place of a compressed-air brake. The plant in question is the *Sikvölgy pit* of the Hungarian *Allgemeine Kohlenbergbau A. G.* in *Tatabanya.*

We also delivered the complete electrical equipment for a *Koepe pulley hoisting engine,* diameter 4·5 m (net load of 3900 kg at 10 m per second from a depth of 586 m) comprising a three-phase induction motor 600 kW at 492 r.p.m., 6000 V, 50 cycles; further, this was the first plant which we equipped with our new travel-regulator.

Fig. 96 shows the stator of one of the D.C. hoisting motors 1550 kW, 45·8 r.p.m., 730 V, mentioned in our second last report and delivered to Pits I and II of the *S.A. Charbonnages de Faulquemont.*

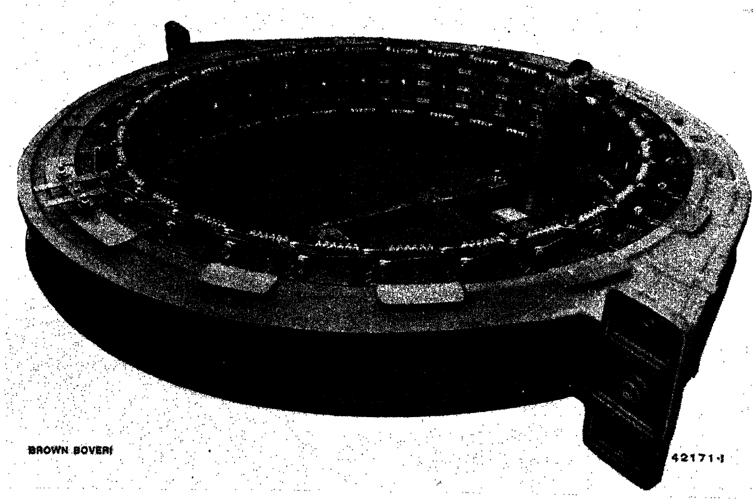


Fig. 96. — Stator of hoist motor Type G 4100/30 f, 1550 kW, 730 V, 45·8 r.p.m.

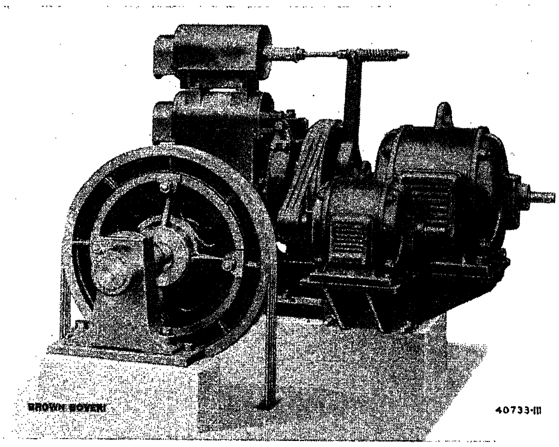


Fig. 97. — Brown Boveri three-phase squirrel-cage motors for practically noiseless running, to drive a lift winding engine.

As to *high-power elevators* (high-speed lifts) we equipped several of these with our practically-noiseless squirrel cage motors; Fig. 97 shows a lift winding engine so equipped with main and auxiliary motor, the later being for inching the elevator into position.

As regards *sluice-gate plants,* we delivered the electrical equipment for the sluice gate bridge of the Klingnau Power Station of the Aare Werke Co.,

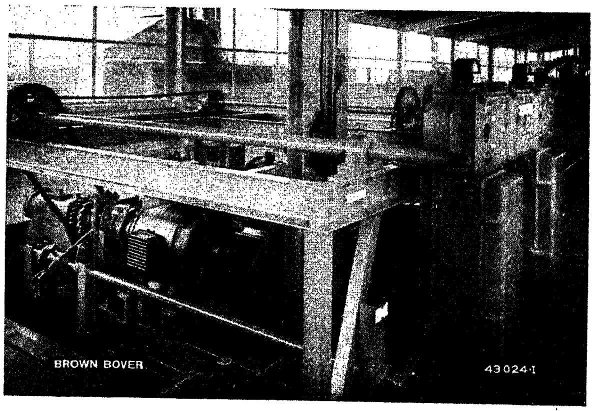


Fig. 98. — Cast-iron clad switching battery on the sluice-gate gear of the sluice gate bridge of Klingnau Power Station.

after delivering those of the Ryburg-Schwörstadt and Albbruck-Dogern stations, equipped in recent years. The Klingnau sluice-gate bridge has four openings each of which has two gate panels. These are each driven by a squirrel-cage motor. Control is by push-buttons either from the bridge or the station proper. The control on the bridge consists of cast-iron clad switching batteries (Fig. 98). These are mounted just beside the driving machinery and they comprise, apart from the push-button control with signal lamps, the requisite contactors and overcurrent relays to protect the motors. There is, also, a float control which acts automatically when the turbines are closed so that the gate position is modified to prevent a rise in the water level above the station. The drive of the *rack-cleaning machine* for this station was also supplied by us. It is built according to the principles of the other similar rack-

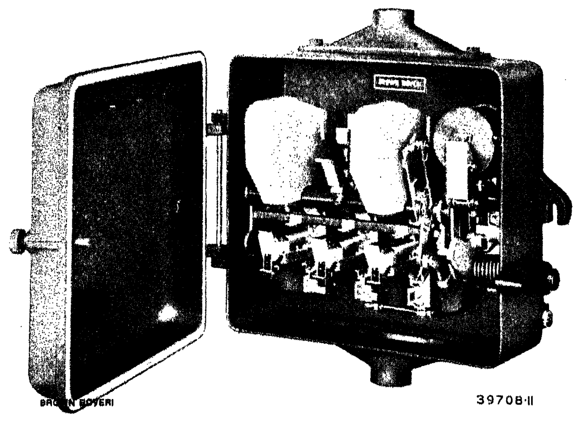


Fig. 99. — Switchbox Type NC 2 for a rated voltage of 500/380 V, rated current 22/25 A.

cleaner drives delivered by us and described in the last January/February number.

As to the apparatus belonging directly to the motor equipment, we would mention our *switchbox Type N for protecting motors*, built for 25 A *with low-volt trip* (Fig. 99) as compared to the earlier designs without this low-volt tripping device. To both types of switchboxes, several additions have been made and special designs brought out. Thus, the number of connecting parts for pipe or cable connection have been increased. The terminals have been designed for taking especially thick wires, auxiliary contacts for connecting up signal circuits were also perfected so that provision has been taken to meet all the conditions which may be met with in putting in apparatus of this kind.

A *universal type of switchbox for protecting motors, Type OM 2 c* for rated voltages up to 660 V A.C. and 440 V D.C. with solenoid control and oil-immersed contacts (Fig. 100) was brought out. A solenoid with

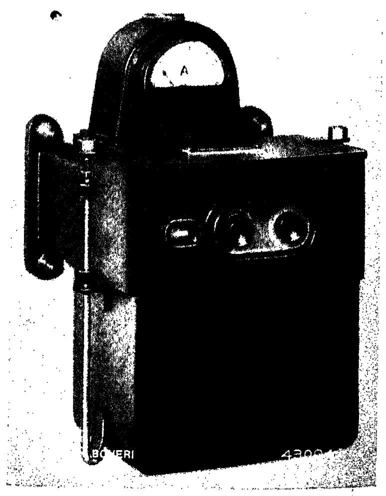


Fig. 100. — Switchbox Type OM 2 c. Rated voltage 660 V, rated current 25 A. Design with push-button switches and ammeter. Leads coming in from below.

its armature and contacting device is in the oil tank which forms the lower part of the switchbox. The upper part is a cast housing; it holds the connections, the thermal releases and other parts, according to the design. If the solenoid coil is excited, the contact device closes, while, if the excitation is cut out, the switchbox is cut out through the action of the tripping springs. The switchbox can be equipped with two push-button switches or else it can be remote-controlled by means of a contact maker, in which case the push-button switches are unnecessary. When the latter are put in, the switchbox can, of course, be connected for remote control, as well. Either the supply system proper or else a separate source of current supplies the requisite current for the solenoid coils. The switchbox can, also, be interlocked with a starter and it can be supplied with built-on ammeter if so desired.

We have perfected our *star-delta switches with thermal release* for 125, 250, and 400 A rated

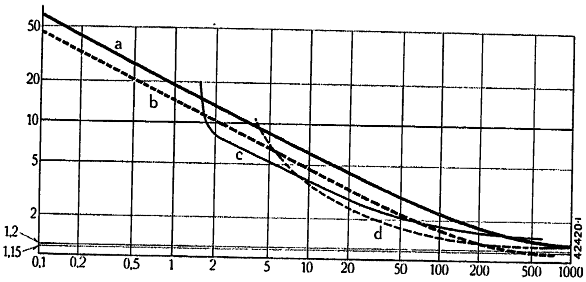


Fig. 101. — Over-current time curves for motors with thermal releases.
a. Motor (danger curve).
b. Release of Brown Boveri type, directly heated up.
c. Release indirectly heated up (heating winding).
d. Release heated up by a transformer.

current which were described, recently, and into the constructive details of which it is, therefore, unnecessary to go, in this report.

We would like to mention here the very marked superiority of our bi-metal thermal releases used in all our motor protection switches and through which the main current flows, this as compared to thermal tripping devices of other kinds. In Fig. 101, a is the danger curve for a three-phase motor, and in accordance with which the motor should be cut out at definite excess-current values. Our thermal releases cause tripping according to curve b which, as regards its character, coincides perfectly with the danger curve to be designated as limit curve and is only slightly below the latter, to allow a margin of safety. The characteristics of indirect or transformer-heated releasing devices are, partly, *very considerably* below the limit curve and, partly, above it, this for very heavy and very light excess currents, respectively, so that the protective switch trips too late under these overloads which are, precisely, the most frequent, that is to say the switch trips after the motor to be protected has taken harm.

Finally, we would mention improvements made on our *push-button switches*, which have been often described, and which are used to actuate remote-controlled apparatus. These switches meet every requirement both as regards their mounting and use for contactor control. They can be used as separate elements or mounted on plates to be lodged in switch panels; they can also be grouped in boxes containing 1, 2, 3 or 4 push-buttons. The push-button boxes can be delivered with built-in interlocking switches or signal lamps.

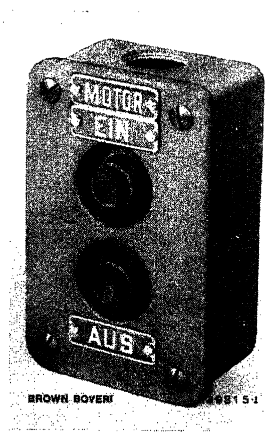


Fig. 102. — Push-button switch box Type D_1 and D_2.

These switches are designed for 10 A rated current and for A. C. and D. C. and can carry an exceptionally high switching load for such small apparatus, which allows of using them for the control of heavy contactors (Fig. 102).

B. ELECTRIC ARC WELDING.

In our last report, mention was made of our *single welding machines*, namely, the *Brown Boveri instantaneous-reaction welding machines* for D. C. arc welding and the welding transformers for A. C. arc welding, which can each be used for one welding site, the current being adjustable smoothly. Certain improvements have been introduced in the course of the last twelve months. Thus, apart from the welding convertor with electric-motor, a new portable welding set, which four men can carry, and weighing 200 kg, has been brought out. In this new set, the welding

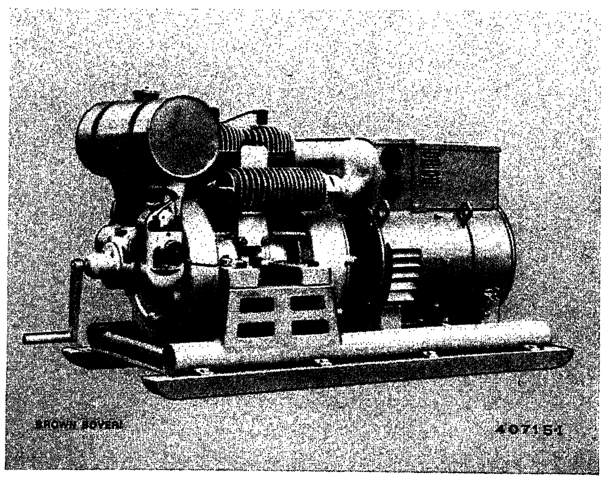


Fig. 103. — Portable welding set with petrol-engine drive.
Weight 200 kg, welding current range 10—180 A.

generator, to deliver from about 15 to 180 A, is driven by a small air-cooled petrol engine (see Fig. 103). The next size, with petrol or Diesel engine and for welding currents of 30 to 300 A, is on four wheels or else designed as a two-wheeled trailer

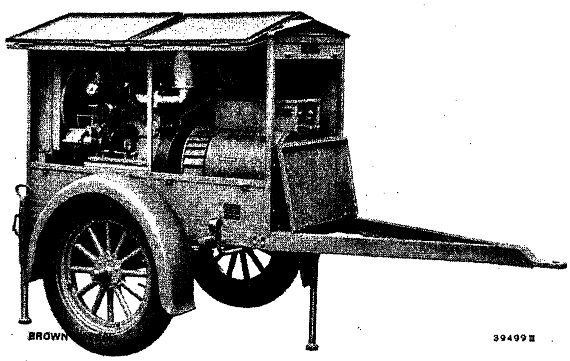


Fig. 104. — Petrol-electric welding set, Type GBSM designed as a two-wheeled trailer, 30—300 A.

to be fastened behind a motor car (Fig. 104). These units are chiefly meant for plants where no current can be tapped for supplying motors or transformers.

In last year's report, mention was made of D. C., *40-V plants allowing welding on several sites at once* and which are very economical in big shops etc. We have equipped several works, ship yards, etc. in this manner and, among these, some having over 100 welding sites; mention should be made of one plant, in particular, having a welding power station and welding regulator, for 245 welding sites.

While on the subject of multi-site welding plants, mention must be made of an important and interesting innovation, namely, our *welding-current regulator for smooth regulation* in the place of *regulation of the welding current in steps.* This is a great improvement in welding technique, as it is very desirable to be able to adjust the welding current to an exact strength for high-grade welding work such as coach building, ship building, etc. The part of our ohmic-inductive welding-current regulator which can be regulated (part II) serves to generate the excess voltage to facilitate ignition and to keep up the arc with a machine-terminal voltage of 40 V, apart from its duty as welding-current regulator. This apparatus is built as a special choke coil with iron core (see Fig. 105). It is provided with a *new kind of winding* composed of two parallel spirals of constantan strip, between which a specially-designed current collector can move easily. Thus, for example, it is possible to attain smooth welding-current regulation between 30 and 300 A. In order that this regulator, by means of which the welder adjust his current, should not be too heavy or cumbersome, a part of the inductance required as well as the resistances to compensate the voltage drop in the different lengths of welding cable, are lodged in a separate apparatus, as was the case formerly (part I, Fig. 106). This apparatus is placed at the bifurcation point on the 40-V distribution bus-bars and not beside the welder. Part I has also been completely made over. The new apparatus has proved the greatest success.

C. ELECTRIC FURNACES.

Our turnover and that of some of our concessionary companies, in this field, showed a very marked increase and this especially in countries in which the connecting up of electric furnaces was encouraged by a far-seeing metering policy. It is an interesting fact that the electric furnace has replaced the coal and gas furnaces, to a considerable extent, even in coal-mining districts.

We have increased the output of our *melting furnaces,* still further and this as regards the transformer output as well as the capacity of the furnace proper. Last year, several furnaces with a capacity of over 20 t were built or ordered, among them, one of 30—36 t charge for the *Société des Aciéries de Micheville.*

For over 15 years, our electro-hydraulic system of electrode control has given great satisfaction and met every practical requirement. The increase of the furnace charge and, particularly the growing popu-

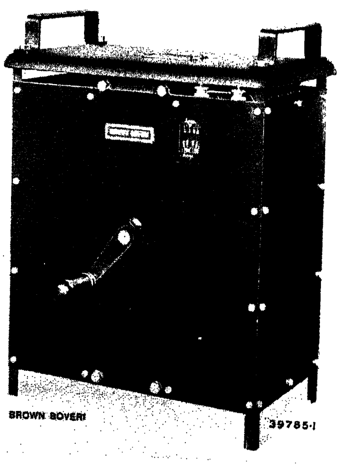


Fig. 105. — Inductive welding-current regulator Type TZ II allowing smooth regulation of welding current, for a plant with multi-welding sites.

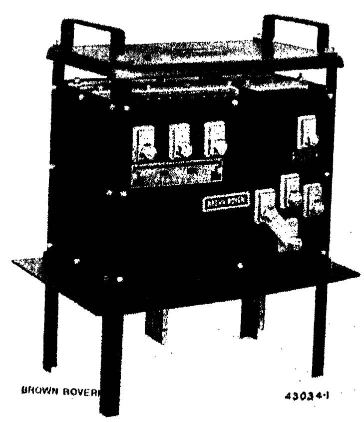


Fig. 106. — New inductive welding-current regulator, Type TZ I, with smooth regulation of welding current, for plants with multi-welding sites.

larity of the electric furnace for refining S. M. and Thomas steel and for making stainless steel of low carbon content made necessary a form of regulation which met the new changed conditions. We, therefore, decided to alter the regulating system of the electrical part while holding to the former constructive design of the regulator as well as of the hydraulic organs. The new regulating system does not regulate the electrodes in function of the current, as the old one did, but does so according to the resistance of the arc, which has certain very advantageous qualities for the operation of the furnace.

When starting up on a cold charge, it often occurs that one electrode comes into contact with the charge before the others in which case a pressure is exercized on the charge according to the weight of the electrode, this may lead to electrode breakages if the charge is not well laid and this, in turn, retards work. The new wattmetric connections eliminates electrode breakages, as the electrode is brought to a standstill when it touches the charge and there is no longer any voltage difference between electrode and charge. The same advantage is especially marked in refining material of low carbon content as any possibility of the electrode dipping into the bath is eliminated. The argument that it is impossible to produce material of low carbon content in electric furnaces, on account of the danger of carbonisation by the electrodes, thus no longer holds good, both practically and theoretically.

The new regulating principle also makes it possible to increase the torque of the regulator and, therewith, its sensibility. On account of this bigger torque, the regulator is equipped with a powerful oil damping device.

Among the *resistance furnaces,* the bright-annealing furnaces take first rank as regards number of plants delivered, last year. In all, we have built up to date 140 of these plants with 200 furnaces and over 2000 annealing pots. The Grünewald bright-annealing process is eliminating all earlier annealing processes using pots with cast-iron turnings as fillings and the same is happening as regards new processes put on the market lately, with and without protective-gas fillings. The Grünewald bright annealing pots have been used, recently, not only for the first object for which they were designed but to anneal in high-vacuum and under pressure with a filling of reactive gas. The possibility of being able to anneal *safely and simply* under the last two conditions opens up to metallurgy quite new possibilities for the treatment of metals.

The hardening and annealing of long steel rods and steel tubes or of those aluminium alloys susceptible to be annealed was a problem which was never solved before. When rods and tubes were drawn out of the furnace chamber they cooled before they could be dipped in the quenching bath and this generally too much and unevenly so that the object pursued by annealing them was not completely attained. We have now created a new type of furnace in which the object treated is cast into the quenching bath in its whole length at the same moment. The time which elapses from the moment the material leaves the furnace chamber until it is dipped in the quenching bath does not exceed a few seconds.

Most electric furnaces are not continually in service, but must be heated up anew for each new process. Our latest furnace designs take due account of this circumstance, by using light-weight refractory linings built in so as to obtain low heat storage. This opens up fresh fields to the electric furnace, which had been closed to it, so far.

The great success of the *glass-bottle cooling-off furnace* reported on, here, last year, convinced a wide circle in the glass industry that this process improved the quality of the glass considerably. In order to improve the economic qualities of this furnace we have replaced the supply-belt conveyor by a special type of mechanical feed. A glass cooling-off furnace of this type was delivered to a Swiss bottle-making works.

The *ceramic industry* is transforming its burning furnaces into electric ones, at an increasing pace, this after the brilliant results achieved had dissipated existing misgivings. The very first plants put to work showed the economic superiority of electrically-heated burning furnaces. We have on order, among others, a double tunnel-type furnace 110 m long, taking 400 kW for a temperature of 1300° C for china and fire-clay and another double tunnel-type furnace, for hard porcelain, 100 m long, which is the first big industrial tunnel furnace for this special purpose.

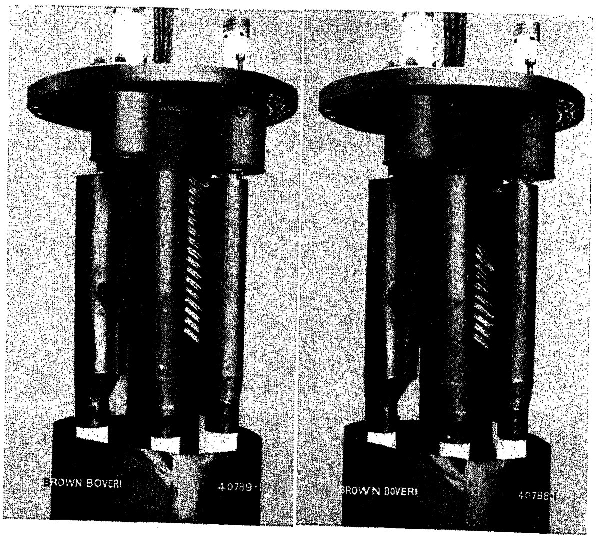
There would appear to be an interesting field of development for the electric furnace of the resistance type in its simplest design as a *coke oven* (generating lighting gas from pit coal). Our tests in this field, begun in 1934, have had certain satisfactory results and we were able to make practical use of the results, for the first time, last year, in a big plant. Electric coking plants are very advantageous waste-power consumers and should have a future in cases where gas works and electric generating plants are under the same management, that is to say when the latter have a considerable amount of waste power to dispose of but are reluctant to sell it to customers, too cheaply, in order not to harm their gas sales. It is, then, advantageous to use this power in the gas works when the latter is equipped with a coking plant.

We have also made very extensive investigations into the turning of D. C. or A. C. of industrial frequency into high-frequency at 300 to 1000 cycles by means of a grid-controlled mutator, this high-frequency current being used to supply a *high-frequency induction furnace, without core.* A field would appear to be opening up, here, to the grid-controlled mutator.

D. THE ELECTRIC BOILER.

The Brown Boveri water-jet electric boiler, put on the market last year, has given an excellent account of itself and 20 units have been put into service or are being built in our shops. The principle on which it is built makes it a high-voltage boiler, its inner resistance being formed of water jets and being considerable. For this reason, the boiler can work with water containing a great deal of salt such as forms naturally in all apparatus working on the evaporating process. It is not necessary to clean the boiler so often or so painstakingly as is usually necessary with standard electric boilers with immersed electrodes, this despite the measures taken in such units to lengthen the track the current has to follow, by building in ceramic parts. Fig. 107 a and b shows the ejection pipe with the water jets as well as the electrodes of a water-jet electric boiler, at half load and at full load. It is seen clearly how the water flows off below without spraying, a result of the special shape given to the Brown Boveri patented electrodes. This prevents flash-overs. There are no ceramic parts immersed in the boiler water, which parts are very quickly destroyed when the water contains soda. The service reliability of the boiler is very high indeed, for this reason, and there are practically no upkeep charges.

Regulation of the water-jet boiler is quite automatic. A steam-pressure regulator governs the throttle valve on the circulating water circuit and thus alters the number of water jets and this varies the output, as required from full load to no load. A special suspended-receptacle type of water-level regulator built according to the diagram shown in Fig. 108 works on the feed valve, keeps up the water level and assures the proper supply of feeding water; when the level of water in the boiler goes down, the receptacle regulator empties gradually, becomes lighter and is, therefore, drawn up higher by the spring on which it hangs. This causes an electric circuit to be closed which energizes the motor controlling the feed water valve so that the latter opens. If so desired, an automatic sludge drainer can be supplied, which keeps the water at that degree of concentration allowable for operation of the boiler. This device is based on the principle that for a given boiler output a definite position of the throttle valve of the circulating water corresponds to a given salt concentration of the water. A current flows in this apparatus, the strength of which is proportional to the electric input to the boiler and an auxiliary current



Figs. 107 a and b. — Electrodes of a Brown Boveri water-jet high-voltage electric boiler :— left, at full load; right, at half load.
By varying the amount of circulating water the level of the water in the central ejection pipe can be regulated and, therewith, the number of water jets to the electrodes. It will be noticed how the water impinges on the electrodes without spraying and then flows off below. The insulators remain quite dry ; there are not ceramic parts in the water (patent).

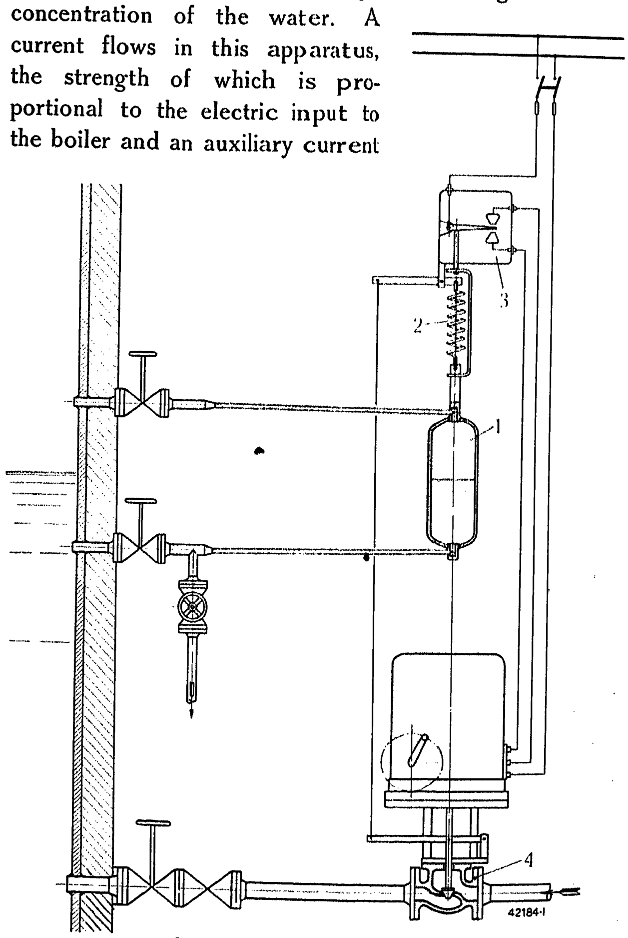


Fig. 108. — Water-level regulator of floating-receptacle type.
As the water-level falls, the suspended receptacle 1 empties and is pulled up by suspension spring 2 and, thus, switches in, by means of relay 3, the electric current to open the feed valve 4.

also flows which is determined by a movable sliding-type resistance which varies according to the position of the throttle valve. By a comparison of these two

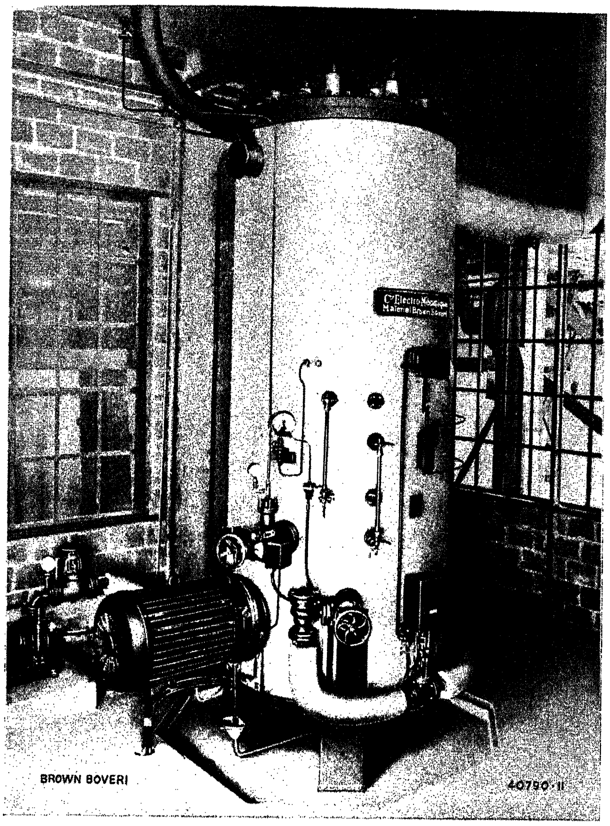


Fig. 109. — Water-jet electric boiler in the Darbley Paper Mill, Bellegarde (France) for 10,000 kW, 7600 V, 8 kg/cm² abs.

currents carried out on an electric bridge, the sludge valve is either opened or closed, through the agency of a small motor. The regulation of the water-jet electric boiler is entirely stable. The pressure of the steam generated is subjected to very slight fluctuations only and the output can be set at any value between zero and full load, which makes it possible to connect the boiler up to the supply system without causing a sudden current surge. The water-jet electric boiler is superior in this respect, alone, to any boiler working on the electrode principle. Figs. 109 and 110 show two new electric-boiler plants, one in Bellegarde (France) and one in Aarberg (Switzerland), with outputs of 10,000 kW and voltages up to 17,000 V. Fig. 111 gives the plan view of an electric-boiler plant with storage belonging to the Falken Beer Brewery in Schaffhausen (Switzerland). The power of this boiler is 2200 kW. The storage capacity can supply the requisite steam for 3 hours, which allows of using cheap waste electric power at night and makes for great reliability of the whole plant.

For a low output range, we have just completed development of a *low-voltage electric boiler;* it is

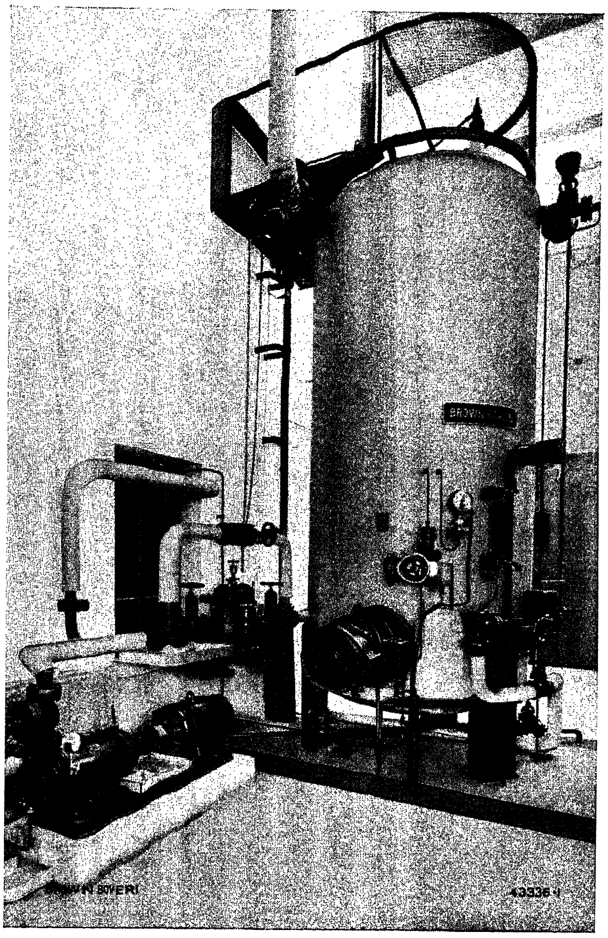


Fig. 110. — Water-jet electric boiler in the Aarberg Sugar Mill (Switzerland) for 9000 kW, 17,000 V, 19 kg/cm² abs.

built for outputs up to 500 kW at voltages up to 500 V and works on the immersed-electrode principle.

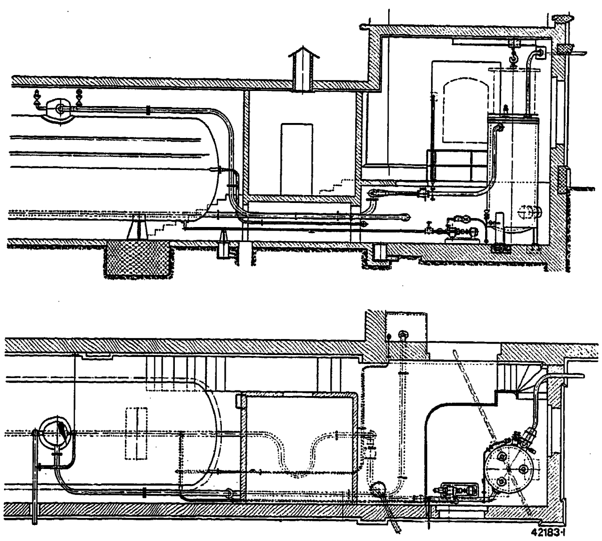


Fig. 111. — Plan of the electric boiler plant in the "Falken" Beer Brewery, Schaffhausen (Switzerland), for 2200 kW, 10,000 V with steam storage.
The storage capacity allows of storing all the steam generated in three hours by the boiler under full load and this allows of utilizing cheaper night power.

This boiler is shown in Fig. 112 and is intended for the generation of steam for small industries:— cheese-making plants, chemical plants as well as for producing hot water in central-heating plants. The water is eva-

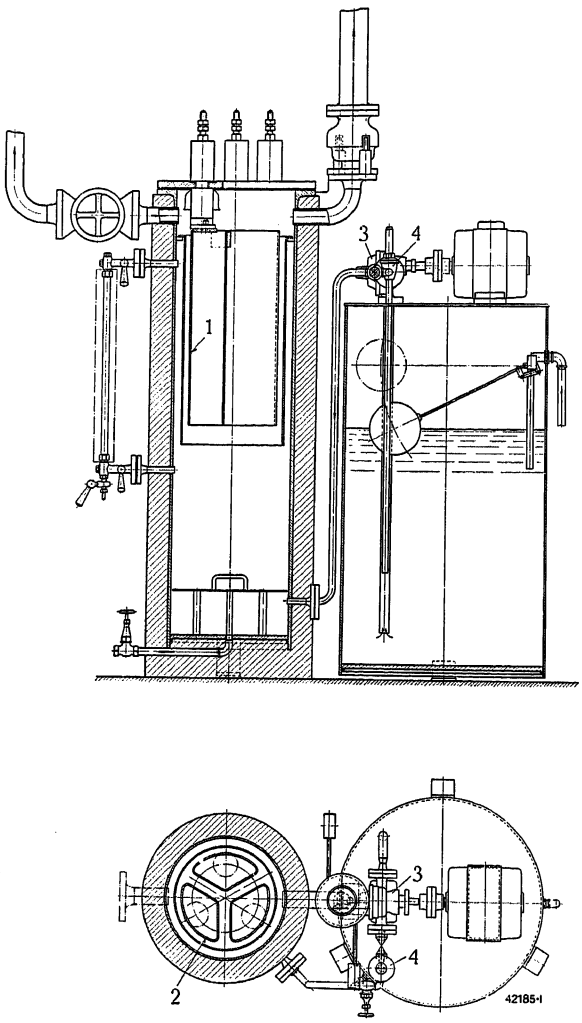


Fig. 112. — Low-voltage electric boiler with immersed electrodes, for output of up to 500 kW at 500 V.

Regulation is of the simplest:— there is a spring-loaded excess-flow valve, inserted on the pressure pipe of the feed-water pump, which maintains the boiler pressure required and, when the pressure rises, allows the feed water to flow away to the feed-water tank.

porated in the *steam boiler* by the well-known method of passing an electric current through sheet-iron electrodes 1, which dip in the water. These electrodes have a sector-like section 2. The electrodes are surrounded by a ring-shaped sleeve which is earthed and thus prevents the current straying to the boiler tank itself with resultant damage to the latter. Regulation is very simple and by steam pressure. An escape valve 4 is built on to the pressure pipe of the feed-water pump 3, which valve keeps the water pressure constant. If the pressure of the steam in the boiler drops, owing to big steam consumption, more water flows from the feed pipe into the boiler, raises the water level, allows the electrodes to be deeper immersed and thus increases the electric power input and the evaporation. If the steam pressure rises, owing to too small steam consumption, the water cannot

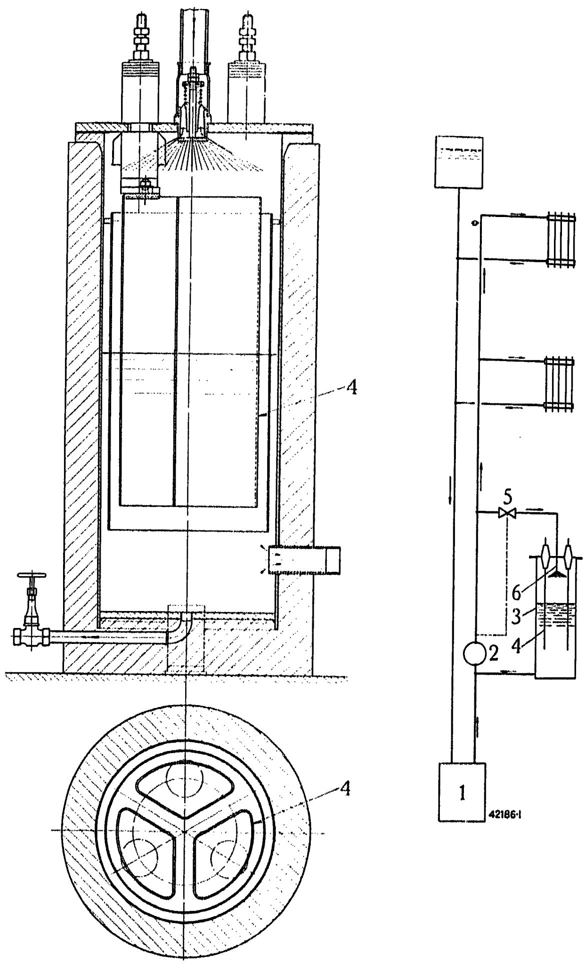


Fig. 113. — Low-voltage electric hot water boiler for central-heating systems, etc.

A part of the circulating water of the heating system is pumped into the electric boiler, by pump 2 through nozzle 6 and is heated by the electrodes. Steam forms in the upper part of the boiler. The steam pressure and temperature of the boiler water correspond to the pressure of the head of water up to the expansion tank of the heating system. The hot water is mixed to that circulating through the system according to heating requirements, by means of a hand valve or valve 5 controlled automatically by thermostat.

flow from the feed pipe into the boiler and it then flows back through the escape-valve 4 to the feed-water reservoir.

The way the *hot-water boiler* works is interesting; it is shown in Fig. 113 in section and diagrammatically, for building into a central-heating system. 1 is the coal-fired boiler, 2 the circulation pump, 3 the electric boiler, 4 the electrodes, 5 a throttle valve through which a flow of water through the electric boiler is produced and regulated, when the pump runs. Steam, which collects in the upper part, is generated as well as hot water in our electric boiler. The water flowing through the boiler is injected in a well-distri-

buted spray by nozzle 6, into this steam chamber. The temperature of the hot water produced as well as the pressure and temperature of the steam generated are set automatically by the height of the building which determines the pressure of the water head of the central-heating system. The heating up of the circulating water in the central heating system is carried out by mixing the hot water generated in the boiler, at about 110—130° C, with the circulating water, in doing which the momentary temperature of the heating system can be varied, as desired, by varying the volume of water flowing in by-pass circuit through the electric boiler by means of the throttle valve 5. If, for example, the heat consumption of the system rises, the temperature of the return flow of heating water sinks. More steam than heretofore will condense in the steam chamber of the boiler through the action of this colder water which is now injected, the steam pressure will fall and allow more water to flow from the heating system and its expansion tank into the electric boiler. This causes the electrodes to be immersed deeper and increases the power input which, in turn, is translated into an increase in steam pressure until equilibrium is re-established with the water head of the heating system. The greater heating requirements have, thus, caused the boiler to take more power, automatically. If the supply temperature is to remain absolutely constant, or be based on the external temperature, this can easily be accomplished by making a thermostat act automatically on the regulating valve 5.

E. COMPRESSORS AND BLOWERS.

1. *Blast-furnace plants.*

The first up-to-date steel works in South Africa, a country extremely rich in iron ores, was put up in Thabazimbi by the South African Iron and Steel Industrial Corp., in 1934, and is now in full operation. The two blast-furnace blowers for delivering 1860 m³/min of air under a pressure ratio of 0·9 to 2·6 kg/cm² abs (Fig. 114) were delivered by Brown Boveri along with steam turbines each of 4550 kW to drive them. The excellent performance of these sets led to a third one being ordered. These blowers have movable diffusors to prevent pumping, which allow of varying the volume of air handled, down

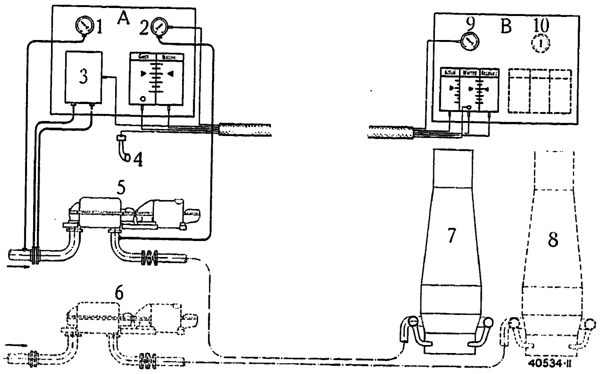


Fig. 115. — Signalling equipment of a blast-furnace blower plant to allow of transmitting orders from the blast-furnace to the blower house, to allow of signalling back reception of the orders and to indicate measurements.

to the lowest loads, while maintaining a high efficiency figure. A remarkable feature of this plant is the signalling equipment, shown in Fig. 115, the object of which is the supervision of the blowers placed at about 150 m from the blast furnaces. The blast-furnace operator reads from his control panel what the pressure and volume of air delivered are at any moment. If he wants to vary the volume delivery he turns a nob thus setting a pointer to the "wanted" volume on his dial. This setting is electrically transmitted to the turbo-blower panel indicating to the blower attendant the "wanted" volume. The blower attendant sets his pointer to the volume on

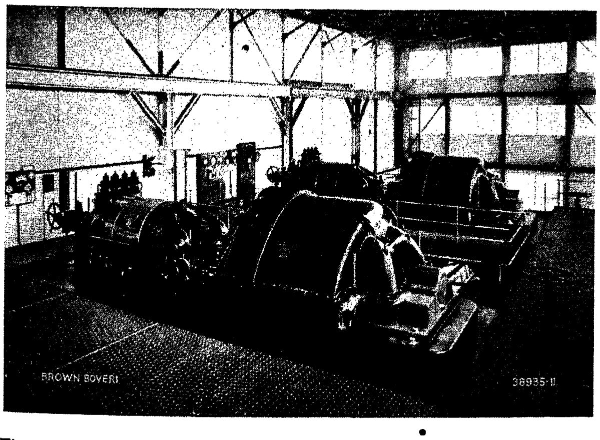


Fig. 114. — Blast-furnace blower for 1860 m³/min of air at 2·6 kg/cm² abs, 4550 kW, in the Thabazimbi plant of the South African Iron and Steel Industrial Corp. Ltd., Pretoria.

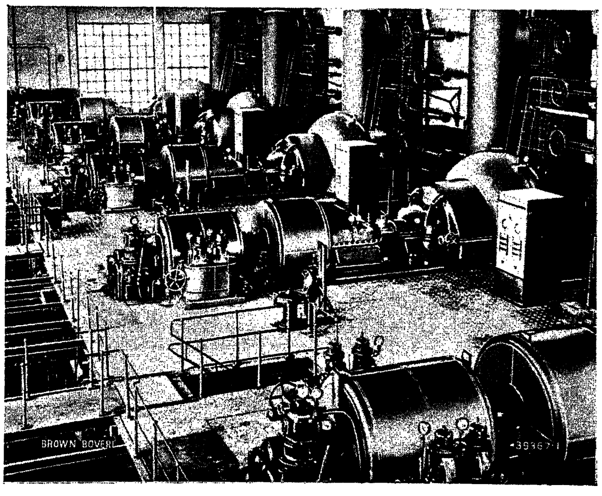


Fig. 116. — Blast-furnace blower plant Kusnetzk (Russia) composed of five blast-furnace blowers each of 3300 m³/min of air at 2·8 kg/cm² abs with two-cylinder steam turbine of 9000 kW. The blowers deliver the air for four blast-furnaces producing 1000 t per day, each.

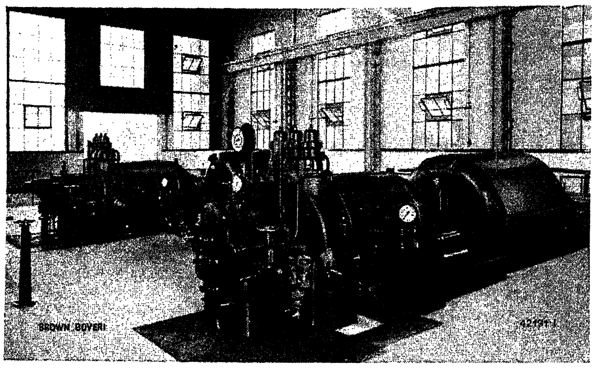


Fig. 117. — Two Bessemer blowers of 800 m³/min of air at 3·5 kg/cm² abs delivered by our concessionaries Richardsons Westgarth, Hartlepool (England) for the newly-built Corby Steelworks, Northamptonshire. The same firm delivered two blast-furnace blowers, each for 1415 m³/min of air, to the same plant.

signal received and this signal appears on the blast-furnace operator's panel, the pointer "received" coming into line with the volume signalled by the "wanted" pointer. The blower attendant then adjusts the turbine and blower until the new volume of air is shown by the volume recorder 3. The reading of the latter is also electrically transmitted to the blast-furnace control panel. There is a klaxon horn which signals to the blower attendant that a signal has been transmitted.

Fig. 116 is a view we received just recently showing the big blast-furnace blower plant delivered a few years ago by Brown Boveri for the Kuznetzk plant. The air blast for four blast furnaces, making 4000 t of iron per day, is delivered by five blowers each built for 3300 m³/min of air at 2·8 kg/cm² abs

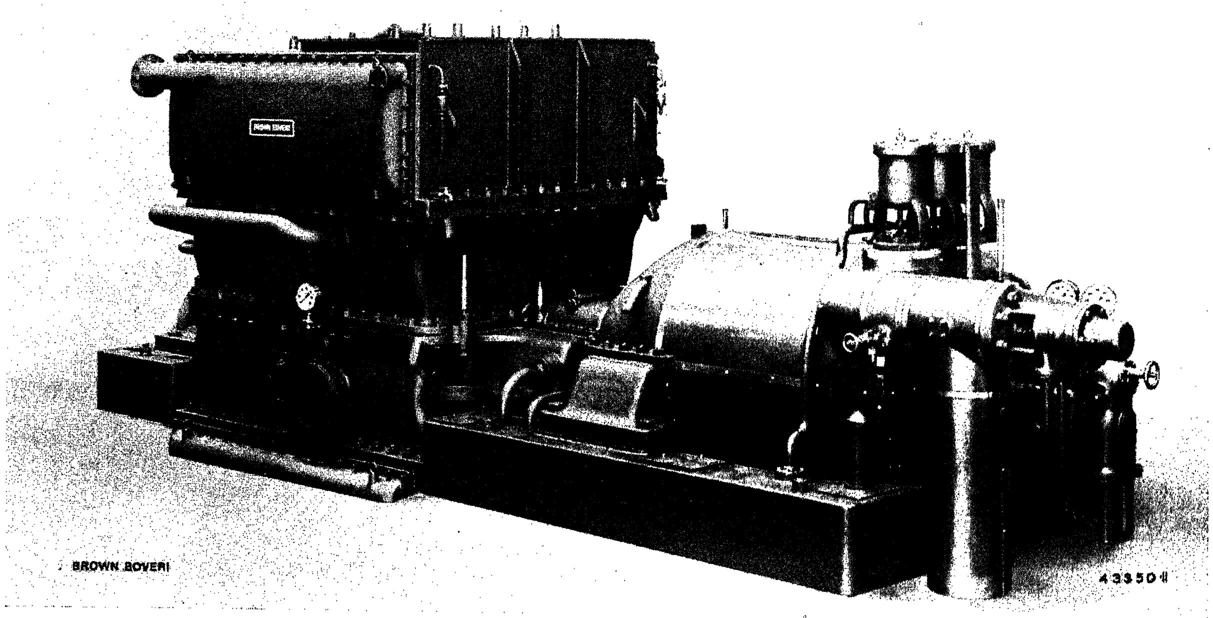


Fig. 118. — Turbo-compressor of the 1935 design delivering 200—400 m³/min at pressures up to 9 kg/cm² abs. The coolers are placed above and below the compressor cylinder.

his "given" dial which corresponds with the "wanted" volume. To show that he has rightly understood the

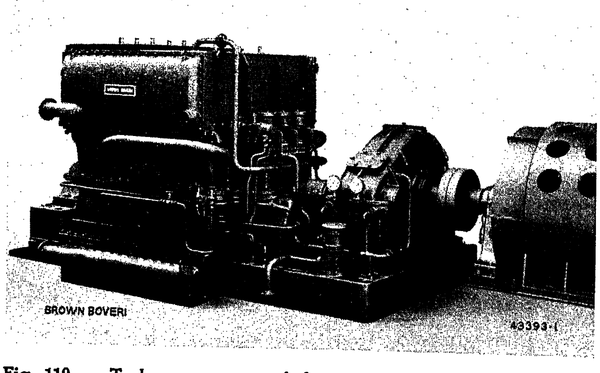


Fig. 119. — Turbo-compressor of the 1935 design driven by a motor and delivering 200—400 m³/min at pressures up to 9 kg/cm² abs.

and driven by 9000 kW two-cylinder steam turbines. These steam turbine-driven blowers are superior in fuel consumption economy to reciprocating gas-driven blast-furnace machinery and constitute a considerable advance on the said gas engines, as regards simplicity of operation, low upkeep charges, small space taken up.

We desire to mention, here, the first blower plant built by Messrs. Richardsons Westgarth, Hartlepool, our British concessionaries, and which is for the new *Corby Steel Works in Northamptonshire.* This blower plant consists, firstly, of two blast-furnace blowers each delivering 1415 m³/min of air at 2·8 kg/cm² abs and driven by steam turbines of 3860 kW output and, secondly, two Bessemer blowers, shown in Fig. 117, each for 800 m³/min air and 3·5 kg/cm² abs, driven by steam turbines of 2900 kW.

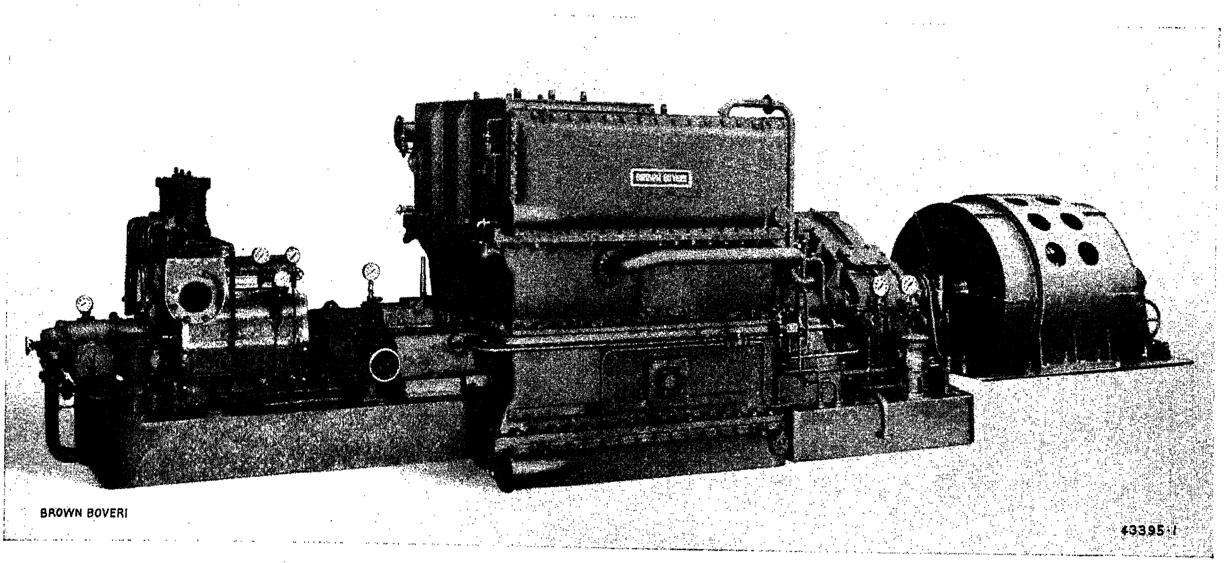


Fig. 120. — Turbo-compressor driven by motor for a nitric-acid works, to deliver 330 m³/min, 8·5 kg/cm² abs, 1780 kW.
The gases exhausted from the process contain some nitric oxide and flow at a pressure of 7·5 kg/cm² abs and at 500° C through an exhaust-gas turbine of acid-proof steel and thus restitutes about 1400 kW to the compressor shaft.

2. *Compressed air generation.*

Figs. 118 to 120 show the latest Brown Boveri turbo-compressor for a pressure up to 9 kg/cm^2 abs and to deliver from 200 to 400 m^3/min of air. This machine has from 9 to 11 wheels lodged in a single casing. The coolers are lodged in two cooler housings. For constructive and technical reasons these are placed below and above the compressor-cylinder proper and not in a slanting position on either side, as in the former compressor type.

This compressor operates without any pumping down to a zero volume of air delivered. The device to prevent pumping does not affect the efficiency adversely, it is simple in design and very reliable. The annoying fluctuations in power input and in the speed, which characterize several types of periodically-working devices for preventing pumping, as well as the unpleasant noise inherent to these devices are two faults entirely eliminated in our compressor.

3. *Compressor plants in the chemical industry.*

A great variety of compressor or blower types are used in the making of ammonia and nitric acid. Thus, Fig. 120 shows one of two compressors delivered to a nitric-acid works, operating on the du Pont-Nemours principle. The compressor delivers

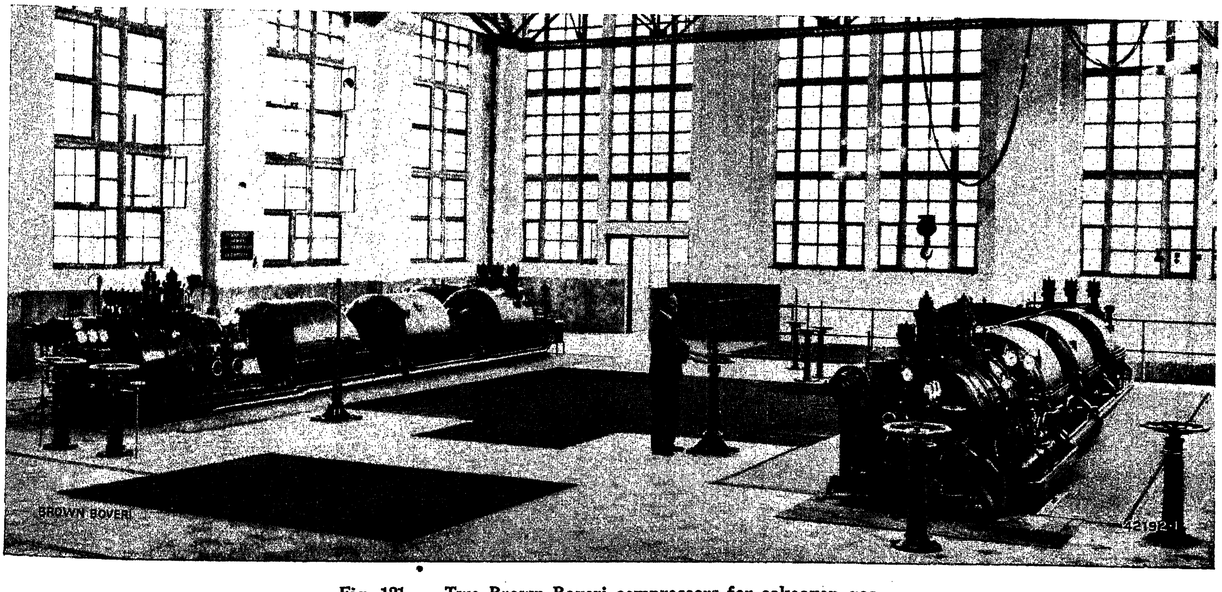


Fig. 121. — Two Brown Boveri compressors for cokeoven gas,
built by our licencees Cockerill in Seraing (Belgium) for the Tertre plant of the Soc. Carbochimique (Union Chimique Belge), to produce ammoniac. The compressor delivers 350 m³/min, 5·0 kg/cm² abs. It is driven by a 1650-kW extraction turbine with extraction at 1·5 kg/cm² abs and with a turbine, built into the third compressor cylinder and driven by exhaust gases which restitutes 325 kW to the compressor shaft.

332 m^3/min of atmospheric air at a pressure of 8·5 kg/cm^2 abs and has a power input of 1780 kW. The gases which are exhausted from the process contain some nitric oxide and flow, at a pressure of 7·5 kg/cm^2 abs and at about 500° C, through a turbine, visible in the illustration, and developing 1400 kW which power goes to reinforce the driving motor on the compressor shaft. The exhaust-gas turbine is composed of a housing, wheels and shaft made of austenite acid-proof chrom-nickel steel.

Further, we have in hand a compressor for nitrate gases intended for a Russian nitrate-acid works. It delivers 315 m^3/min of gas at a pressure of 7·4 kg/cm^2 abs, is water cooled and composed of a housing and wheels built-entirely of acid-proof chrom-nickel steel. There is, also, an exhaust-gas turbine, here, to utilize the exhaust gases. It is not, however, in a separate housing, like the last one mentioned, but placed in the cylinder of the compressor, itself. The exhaust-gas turbine in question delivers 360 kW back to the compressor shaft, when supplied with gas at 5 kg/cm^2 abs and 100° C.

Fig. 121 shows a very remarkable compressor plant delivered by our licencees Cockerill in Seraing, Belgium, for the *Tertre plant* of the *Soc. Carbochimique (Union Chimique Belge)* and built for making ammoniac. The compressor compresses and delivers about 350 m^3/min of coke gas at 5·0 kg/cm^2 abs. This gas contains Benzol as well as tar and naphtalin. Special care must, therefore, be paid to the devices for elimination and carrying off of the impurities. A condensing turbine of 1650 kW output with extraction of steam at 1·5 kg/cm^2 abs drives the compressor. A recuperation turbine is built into the third compressor cylinder in which the gases which are exhausted from the apparatus can expand. This turbine delivers 325 kW which is recuped on the compressor shaft.

F. REFRIGERATION.

1. *The Frigibloc.*

These cooling equipments with compressor, motor, condenser and evaporator all lodged in a gas-tight casing are built for outputs up to several million kcal/h and a model has been brought out, quite lately, for as little as 50,000 kcal/h. The biggest plant built up till to-day is one for an artificial-silk mill, producing 1,200,000 kcal/h at —13° C. The Frigibloc has now been completed by the addition of an automatic drying device which separates out the water absorbed in the cooling medium and which has penetrated into the Frigibloc along with the air when the apparatus was filled. Small quantities of water, as well, which have penetrated to the cooling medium, owing to defective sealing of the water system, are eliminated, almost entirely, by this drying device. This eliminates danger of rust and deterioration of the motor windings. In the case of the ingress of bigger amounts of water, which may occur if a cooling tube bursts, there is an automatic water indicator which acts and warns the operators. In building the cooler and evaporator and in testing and putting in the cooling tubes we were able to put experience gained, over 40 years, in the building of condensers to good account as well as the more recent investigations, carried out in our metallurgical laboratory, on the resistance to corrosion of brass and copper tubes and this has allowed us to practically eliminate leakages of the water system.

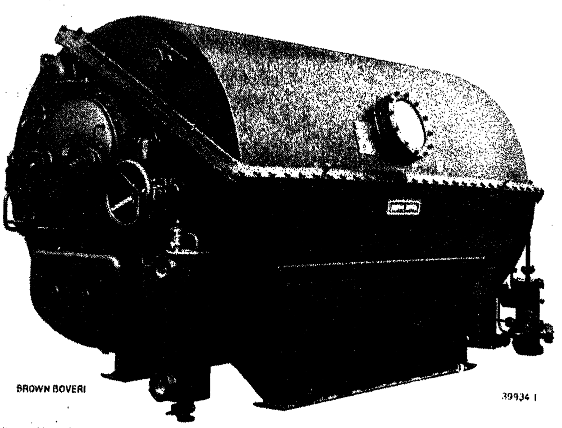


Fig. 122. — Frigibloc in cylindrical housing of 1935 design, for 200,000 kcal/h and —14° C, intended for an artificial silk-mill in Spain.
This housing contains the whole cooling equipment comprising the motor, compressor, condenser, evaporator as well as all auxiliary and regulating apparatus; the whole is gas-tight enclosed. The gas pressure is smaller than atmospheric pressure, so no gas can escape. The bloc is safeguarded against trouble by automatic devices and, thus, requires no attendance. It is especially suitable to industrial plants and to branches of trade where specially trained attendants are not available, because it takes up so little room and requires so little supervision. The gas-tightness feature makes the Frigibloc especially suitable for hotels, theatres, etc.

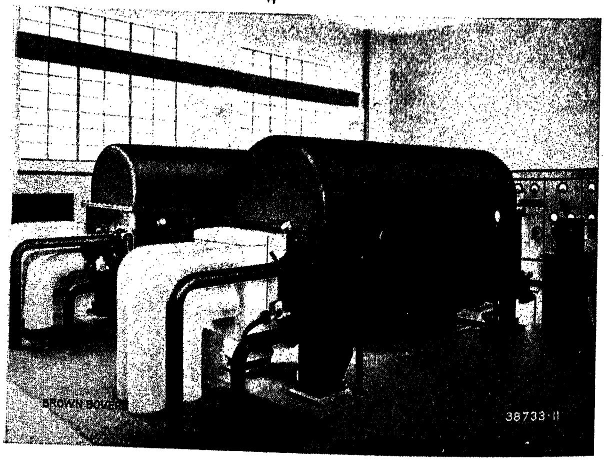


Fig. 123. — Frigibloc with two temperature stages.
The turbo-compressor as refrigerating machine allows of two temperature stages being attained. In a Frigibloc for 250,000 kcal/h at —14° C and 350,000 kcal/h at 0° C it was found feasible to save 16% of the power input required by means of two-stage refrigeration.

Fig. 122 shows a Frigibloc of the latest design in a cylindrical-shaped housing and built for 200,000 kcal at —14° C. This shape of housing facilitates manufacture and permits of a more advantageous layout of the stacks of tubes and of auxiliary apparatus.

An interesting development is the Frigibloc with subdivided evaporators, so as to obtain two temperature stages. A plant of this description with Frigiblocs for 250,000 kcal/h at —14° C and 350,000

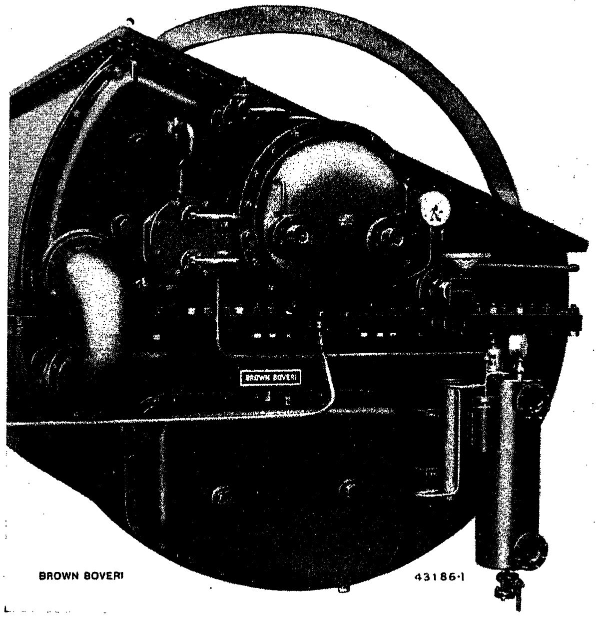


Fig. 124. — Frigibloc for Crown Mines, South Africa, 845,000 kcal/h at 7·5° C, to cool the gold mines which are 2000 m underground.

The bloc is divided into three parts to allow of lowering it complete down the narrow shaft which measures only 1220×3500 mm.

kcal/h at 0° C has been ordered recently for a chemical works. The compressor has two suction branches, of which the first is connected to that part of the evaporator for lower temperatures and delivers the refrigerant to the condenser after passing it through six impeller wheels. The second suction branch takes off refrigerant from the warmer part of the evaporator, the refrigerant then being passed, together with the vapour from the first circuit, through the last four impellers to the condenser. This two-stage design resulted in a saving of power used of about 16% as compared to the refrigeration of the whole in one stage at —14° C. Fig. 123 shows a two-stage Frigibloc. We desire to say, however, that the two-stage character requires a certain alteration in the building and is only suitable when the temperature difference of the stages corresponds to the pressure difference of one impeller, that is to say about 10° C and when the refrigerating output required at the higher evaporating temperature is sufficiently great, and is at least of the same order as the refrigerating output required at the lower temperature stage.

The compact design of the Frigibloc makes it especially suitable to mines. Fig. 124 shows a unit for the Crown Mines (South Africa). The shaft which extends down to 2000 m below the level of the earth has a relatively small section of 1220×3500 mm. By a subdivision of the Frigibloc it was found possible to so build it that it could be lowered down the mine shaft in practically complete condition, down to the pipe flanges. This unit generates 845,000 kcal/h at + 7·5° C and with cooling water of 28° C.

It should be said here that we have succeeded in making our motors for Frigibloc plants quite impervious to attack from the refrigerating medium used, this by special treatment of the windings.

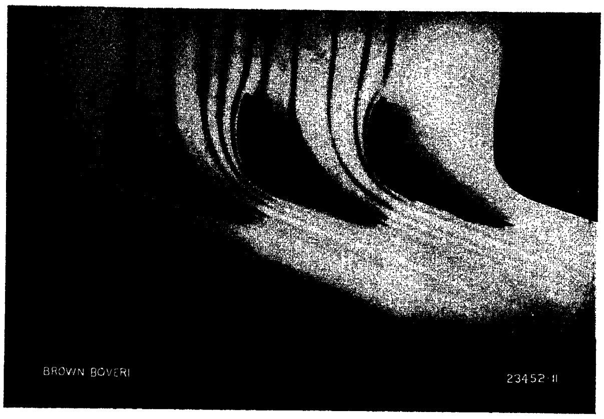


Fig. 125. — Illustration from a report on stream-line experiments made in the years 1926 and 1927.

With the help of laws of similarity the flows in incoming and outgoing ducts of steam turbines, compressors and pumps as well as in blades and blade grids for turbines and axial-type compressors, were investigated, this being done by means of models.

G. AERODYNAMICS AND AEROPLANES.

Our firm has done a great deal of pioneering work in the field of turbo-machinery developments with the object of furthering researches in steam-line problems. The inlet and outlet ducts in stream turbines, compressors and pumps were developed with the help of scale models and investigations into flow were carried out on blades and blade grids of steam turbines, all with the object of improving the efficiency. These tests have been crowned with great success. We would recall, our 1926—27 tests, reported on briefly in The Brown Boveri Review of 1928 (see Fig. 125). Work done in this field and our development work on the axial compressor, caused us to take up the building of experimental wind tunnels for aerodynamic model testing on carrying surfaces, on propellers, aeroplanes, projectiles, etc.

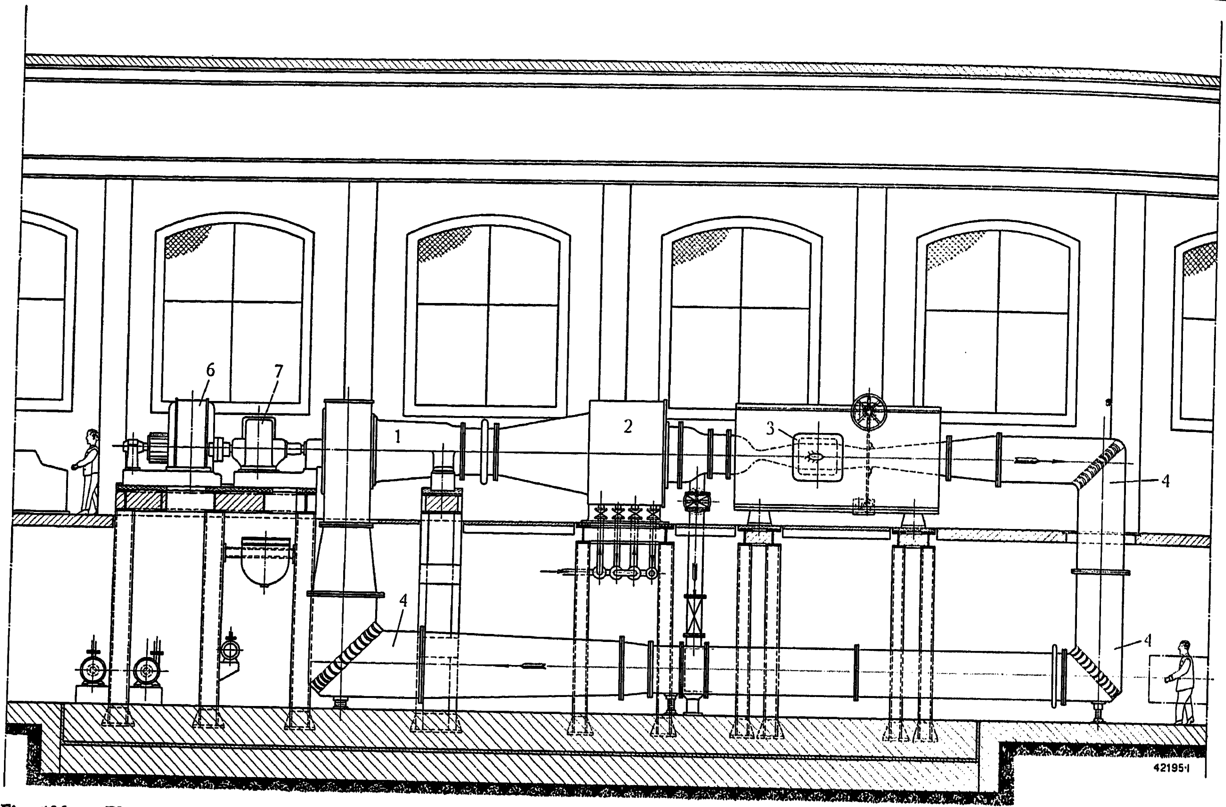


Fig. 126. — Plant of the wind tunnel for super-sound velocities of the Aerodynamic Institute of the Swiss Federal Institute of Technology, Zurich. Plant designed by Prof. Dr. Ackeret, Principal of the said Institute.

There is a 1000-kW D. C. motor to drive the axial compressor. In the super-sound velocity measurement tunnel an air velocity of 2300 km/h can be attained but only under a vacuum of about 0·2 kg/cm² abs.

1. Axial compressor. 2. Air cooler. 3. Measurement tunnel. 4. Return flow channel. 6. D. C. motor. 7. Reduction gear.

Working in collaboration with *Prof. Dr. Ackeret* of the Swiss Federal Institute of Technology, Zurich, we designed and built the axial blower with its 1000-kW driving motor as well as the cooler for a wind tunnel for super-sound velocities which is in the Aerodynamic Institute of the Mechanical Laboratory, in Zurich. A similar plant of double the output was designed in collaboration with Prof. Dr. Ackeret for the aerodynamic testing plant Guidonia in Italy. The plant was built by our concessionaries the Tecnomasio Italiano Brown Boveri, Milan. As it seems quite certain that greater interest will be aroused for plants of this description, in the near future, we think it of interest to show, again, a plan view of the Zurich plant (Fig. 126). The wind tunnel is composed of the axial compressor 1, the air cooler 2, the measurement and testing tunnel proper 3 and the return-flow channel 4. The guidance of the flow of air in the corners, by means of blade grids is worthy of note. The whole tunnel is brought down to a pressure below the atmospheric by means of a vacuum pump, in order to keep the power required down to an admissible value. The blower of the Zurich air tunnel is built to deliver 55 m^3/s of air and for a pressure ratio of 0·125 to 0·275 kg/cm^2 abs at 3400 r. p. m. The speed can be raised to 3800 r. p. m. which corresponds to a speed equal to twice that of sound in the measurement tunnel. The D.C. motor 6, of 1000 kW, drives the compressor through reduction gear 7. It is supplied with current from a Ward Leonard set and its speed can be varied between 1000 and 3800 r.p.m. The cooler must carry off from the system the amount of heat corresponding to the motor power supplied in so far as it is not dispersed by radiation and it brings the temperature of 120° C generated in the compressor down to 45° C again. The cooler is composed of a first part with ribbed tubes and a second part of the plate type which also serves to impart a parallel direction to the streams of air passing through it (Fig. 127).

The testing and measuring tunnel proper, which can be got at after the removal of a cover, is shaped, in the inside, as shown in Figs. 128 and 129. In order to generate wind velocities superior to that of sound, a nozzle is necessary the first part of which narrows down to a very small section in which the velocity of sound is attained the second part being divergent and in which the air is accelerated to higher velocities

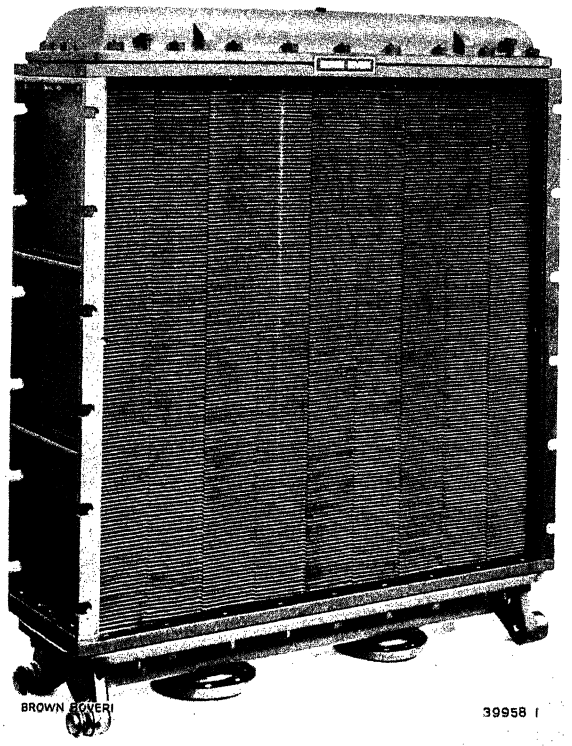


Fig. 127. — Air cooler and, at the same time, parallel rectifier of air flow of the super-sound velocity wind tunnel of the Aerodynamic Institute of the Swiss Federal Institute of Technology, Zurich.

55 m³/min of air are cooled from 120 to 45° C and the energy transformed into heat, which is imparted to the air by motor and blower is, thus, eliminated.

than that of sound. This enlargement is necessary, because, when the pressure drops, the gas is less accelerated than the specific volume increases. A diffusor is placed at the other end of the super-sound testing tunnel; in this diffusor the kinetic energy is retransformed into pressure energy, so as to save motor power. Contrary to the design of an ordinary diffusor for velocities lower than sound, the diffusor for higher velocities has a first convergent part as, when the pressure rises, the air is less retarded than the specific volume decreases. After going below the velocity of sound, which prevails in the narrow section of the diffusor, the air passes to an ordinary divergent diffusor.

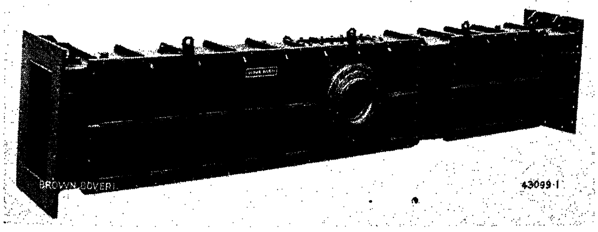


Fig. 128. — The super-sound velocity measurement tunnel proper of the wind tunnel, closed.

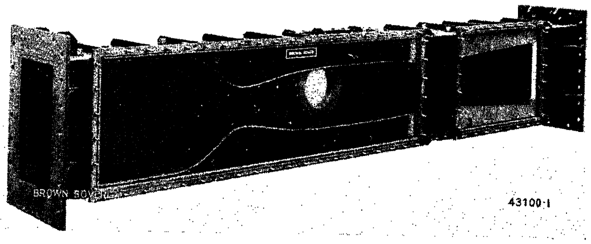


Fig. 129. — The super-sound velocity measurement tunnel proper of the wind tunnel, shown open.

From left to right: — The inlet nozzle with first restriction in which the velocity of sound is attained. Then comes a widening in which super-sound velocity is reached. The measurement tunnel proper is in the region of the observation pane, between parallel partitions. There now comes a slight restriction in which the pressure rises and the velocity falls to that of sound. After this, comes a divergent diffusor in which the velocity of the air is reduced to a value corresponding to the section of the wind tunnel. The shape of the measurement tunnel depends very much on the pressure and temperature of the air and must, therefore, be designed so as to be easily altered. To this end it is formed of wood on the inside of the pressure tight tunnel. About 60—70 % of the power transformed into speed are restituted in the diffusor.

The pressure characteristic along the length of a wind tunnel, for velocities higher than that of sound, is shown in Fig. 130, for different velocities and it is seen that diffusor efficiencies, referred to pressure, of 60—70 % can be attained. The flow of air is very unstable especially in the super-sound part of the diffusor and the slightest deviation from the proper dimensions, pressures or temperatures lead to pressure shocks and disturbances in the flow. For this reason, the super-sound tunnel and the measurement tunnel have been designed of square section between parallel side partitions; it is provided with a removable cover

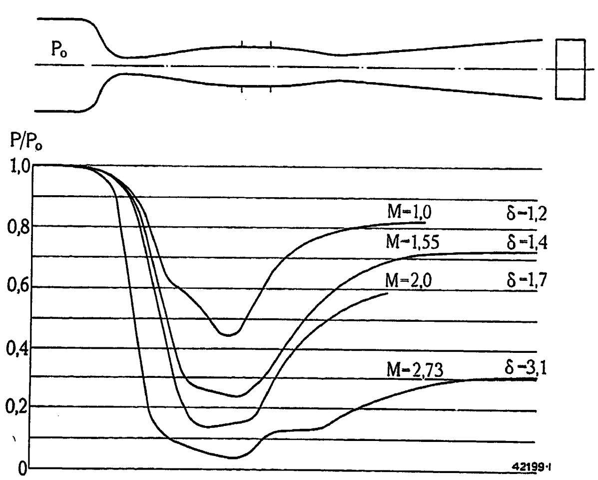


Fig. 130. — Pressure curves in the measurement tunnel proper of a super-sound velocity wind tunnel, at various speeds, according to Dr. Ackeret.

M. $\frac{\text{measurement velocity}}{\text{velocity of sound}}$

δ. The pressure ratio to be produced by the blower.

The wind tunnel for super-sound velocity has a convergent-divergent nozzle, followed by the measurement tunnel proper with the super-sound velocity desired and then a convergent-divergent diffusor in which the pressure is partly restituted, as is shown in the curves; to each super-sound velocity there corresponds a specially adjusted channel, as is shown, for example, for curve M=2·73.

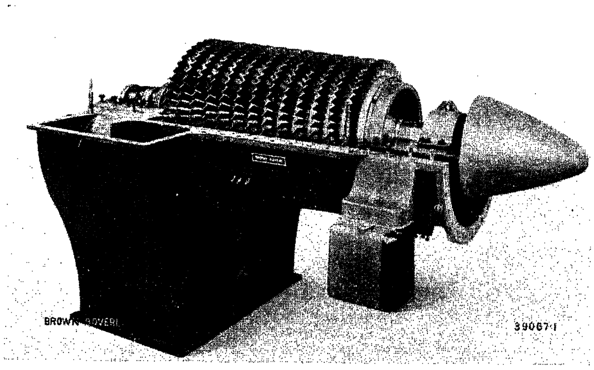


Fig. 131. — High-pressure axial blower for a super-sound velocity wind tunnel.

The volume of air delivered can only be slightly varied at a given speed at constant pressure. This type of blower is, however, very suitable to the requirements of the present case because the pressure generated by the blower changes exactly as does the resistance of the wind tunnel, that is proportionately to the square of the air volume passed and the square of the speed. The variations in air volume for different test conditions is, thus, carried out by altering the speed of the blower which is possible with the help of a D. C. motor fed from a Ward Leonard set.

and equipped with built-in wooden parts which allow of changing the section, easily. The proposal was also made to build a measuring tunnel the section of which could be altered and set from without, during service, and to use for the purpose a strip of steel, wood, etc. which would be movable and being properly guided and supported, could be set as desired.

Fig. 131 shows the multi-stage high-pressure axial blower the blading of which is designed according to wind-tunnel experiments and which is used, in the plant just described, for making tests and also for tuition purposes.

The power required to operate wind tunnels of this kind is very considerable especially as the mass of the objects tested gets greater and approaches full-scale size. Thus Prof. Ackeret calculates that 25,000 H. P. would be necessary for a high-velocity wind tunnel with a wind velocity of 700 km/h at atmospheric pressure and a diameter of testing tunnel of 4·5 m. For outputs of this size, motor drives cannot be used and *Ackeret suggests driving the compressor of the wind tunnel by a steam turbine with Velox steam generator.* The Velox would be very suitable here, as it produces no smoke and can be placed in densily populated town quarters, which are generally those in which scientific institutes are located; another great advantage is the rapidity with which it can be started up and cut out. The higher cost of oil fuel, as compared to that of coal, plays no part, here, as this is an experimental plant running for short times and burning very little fuel, in all.

To this field, belong altitude-test stands for aeroplane motors built by Brown Boveri for all conditions. In these test stands, these pressure and temperature conditions of the atmosphere are reproduced which are encountered by planes at altitudes of 6—10,000 m. Fig. 132 shows one of these Brown Boveri stands in which atmospheric air is cooled, in a cooler of a refrigerating machine, and dried and then brought down with further cooling to the desired state for the aeroplane motor by expansion in a turbine. The motor exhaust gas is also cooled and expelled to atmosphere through a compressor. The aeroplane motor is placed in a wind tunnel and subjected to a wind the velocity, pressure and temperature which correspond to the real conditions to be met. A second cooling machine, with suitable cooler, cools the wind tunnel.

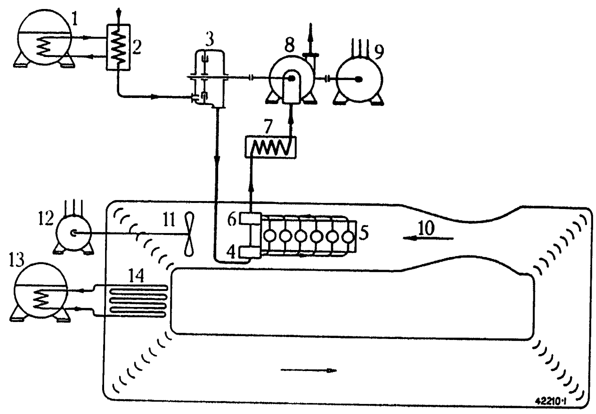


Fig. 132. — Layout of a test bed to test aeroplane engines under high atmospheric conditions.

Atmospheric air is cooled down in Frigibloc 1 and cooler 2 to about −30° C. It is then expanded in turbine 3 down to about 0·3 kg/cm² abs at −50° C and its condition then corresponds to air at about 10,000 m altitude. This air is now fed, through a charging blower 4, to the aeroplane engine 5. The exhaust gases of the engine expand in an exhaust-gas turbine 6, are then cooled in a cooler 7 and driven out to atmosphere by a compressor 8. Further, the motor is placed in a wind tunnel in which the high-atmosphere conditions are reproduced; thus not only is it supplied with combustion air at high altitude conditions but is also subjected to a corresponding stream of air as when in movement. The low wind-tunnel temperature is produced by a second refrigerating machine 13 with suitable cooler 14.

IV. TRACTION.

A. ELECTRIC LOCOMOTIVES AND COACHES.

It is encouraging to note the maintained activity which characterizes this field and which allowed us to proceed with the development of our traction equipment. Speaking generally, however, this development work has not affected electric locomotives primarily, because most railway managements either judged themselves to be amply equipped with locomotives already, or else only placed repeat orders, for units to replace others of known and approved types. The pressing necessity of wooing back part of the public, drawn away by road competition, forced the railways to transform part of their traffic system by the introduction of light fast-running motor coaches or motor coach trains operating at greater frequency, on certain line sections.

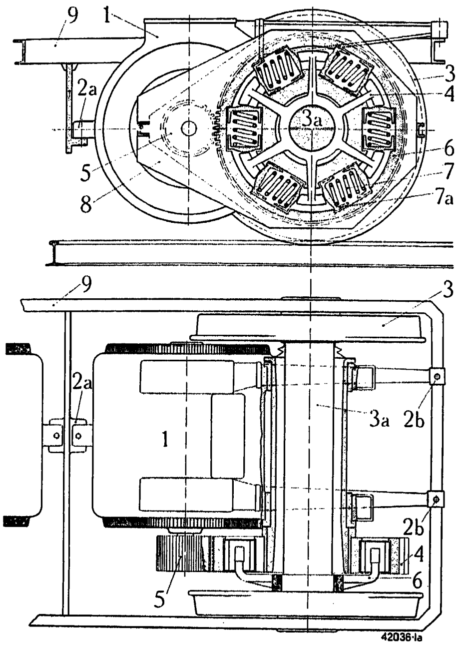


Fig. 133. — General layout of motor drive of light motor coach Type CLe 2/4 No. 202 of the Swiss Federal Railways.

1. Motor.
2 a. Suspension of motor.
2 b. Motor support on the jack-shaft side.
3. Driving wheel.
4. Carrier spider.
5. Pinion.
6. Big gear wheel.
7. Drive springs.
7 a. Spring cups with gliding surfaces for spokes of carrier spider.
8. Shield of gear.
9. Upper frame of bogie.

We had seen this development coming, years ahead, and as early as the spring of 1928, we studied, along with the management of the Swiss Federal Railways, the question of the building of light, fast-running motor coaches for one-man control, to improve traffic conditions on Swiss lines. From the very start, it was clear to us that many parts of the new coaches to be designed could not simply be taken as they were from existing types of motor coaches and locomotives. A new drive was required here, to meet the speeds and the wheel diameters considered, as the ordinary nose-suspended motor would not be able to meet the far more stringent demands as regards light weight, high speed and perfect commutation with a minimum of unsprung load. Our *spring-type drive* was developed to meet these requirements (Fig. 133). This drive was placed on one of the two light motor coaches of the Swiss Federal Railways (Fig. 134) which were put into service in 1935/36 and was described in a recent number of The Brown Boveri Review. The driving motor is rigidly secured to the bogie frame; its torque is transmitted through the big gear wheel and a carrier spider secured on the axle of the driving wheel. The six arms or spokes of the carrier spider engage between the spring-bearing cups, with spherical friction surfaces, of the driving gear wheels. The spokes of the carrier spider can slide along the front wall of the spring cups and thus allow play to the relative movement between the big gear wheel and the driving axle due to the motor being a rigid part of the bogie frame. Our spring drive has been so successful that the Swiss Federal Railways have decided to equip with this drive all four coaches of the same type and design ordered last summer. There are no doubts remaining in Swiss traction circles that a spring drive of this kind is essential for travelling speeds of over 100 km per hour.

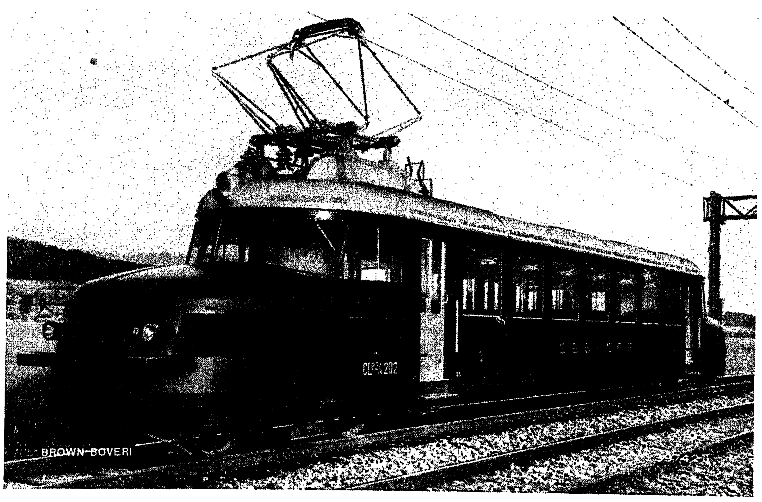


Fig. 134. — Light motor coach Type CLe 2/4 No. 202 of the Swiss Federal Railways.
Showing coach in service conditions. The whole electric equipment is in the forward structures and on the roof. Only the ventilating set for electric coach heating by air is under the floor.

As regards electrical apparatus, the *control equipment*, in particular, has been developed to meet the particular requirements of motor-coach service. In the first place, a light and simple type of control organ had to be evolved which, despite lack of space due to dimensions being restricted, had to be able to stand up to frequent switchings; in the second place the control had to be in very gradual steps so that, for the duration of the starting period, the highest tractive effort, compatible with adhesion, could be kept up with as few fluctuations as possible, while the fulfillment of this second condition had not to be contrary to that of the first one.

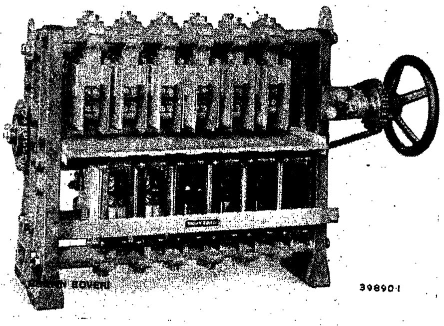


Fig. 135. - Light motor coach of the Berne-Schwarzenburg line. Cam-type controller for ten travelling positions, designed for drive by motor or by hand, one-hour current rating 2×540 A, continuous current rating 2×240 A.

Our step switch (Fig. 135) for the *light motor coaches* of the *Berne Schwarzenburg line* controlled by the Berner Alpenbahn Gesellschaft (Fig. 137) mentioned here last year were developed according to these principles. This is a cam-type controller with individual switching elements for the different steps, which always switch under current and are equipped with blow-out coils for that reason; it also has a special pair of switching units which in switching over from step to step, insert or withdraw a transition resistance between the said steps. An electro-motor-driven cam controller, of similar design, is also used on four new A. C. motor coaches with each four driving axles for the *Norwegian State Railways* (Oslo-Ski line section) having a total one-hour output of 4×157 H.P. at 41 km/h, but which cannot properly be designated as light motor coaches. The individual switching units of the controller, used here, work on the motors through a preventive coil (voltage-dividing choke coil), in the usual way when contactor controls are employed. The growing tendency to do away with a main circuit breaker in motor coaches and to divert primary overload currents by a horn type of high-voltage fuse and a ground bar, leads to a layout with overload contactors, electro-magnetically or electro-pneumatically controlled, and inserted on the motor circuit, with overcurrent releasing gear.

The principle we apply in our low-voltage regulation (see page 32, Fig. 61) and in our welding current regulators for multi-welding sites, with continuous smooth regulation by means of an uninsulated transformer winding on which a current collector glides, should be, in our opinion, the most perfect solution as regards simplicity of design combined to precision of setting.

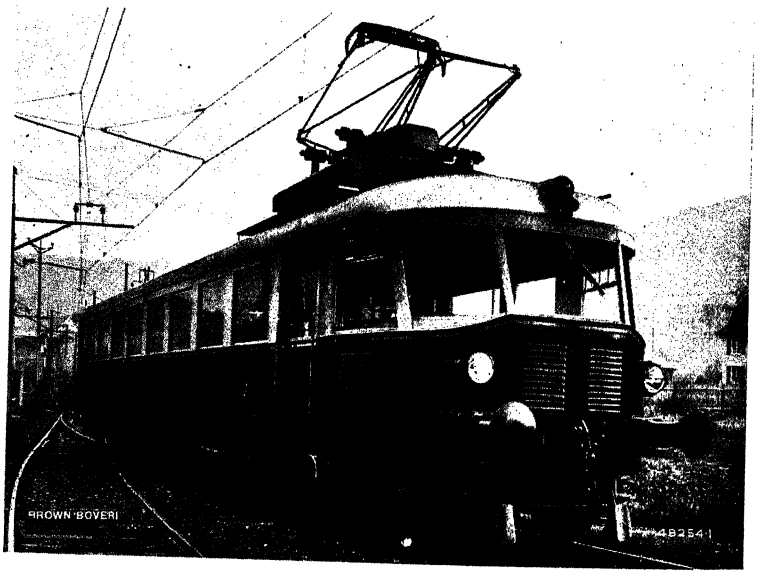


Fig. 137. — Light motor coach No. 787 for the Berne-Schwarzenburg line. Highest speed 90 kg/h, 15,000 V, 16⅔ cycles, 65 passengers seated, 50 standing.

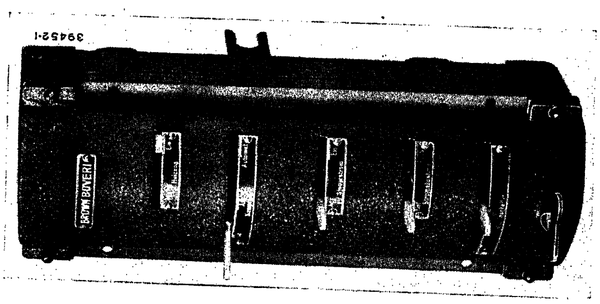


Fig. 136. — Control switch boxes holding up to six small lever switches on the energizing current circuit, with interlockable switching levers.

In this connection we would mention the remote control of all auxiliary services of electric coaches by means of our *new control switch boxes* (Fig. 136) which contain small switches for natural control. These can be used both for different auxiliary services such as current collector, compressor, heating and lighting and for the control of the reversing switch as well and thus help to relieve the controller.

These control switch boxes are especially suitable to drivers cabs where the driver is in a sitting position, as they take up little room and can be comfortably actuated from the sitting position. The built-in switching units are dimensioned for 20 A D.C. for control voltages up to about 50 V and are all of the snap-closing type. We had an opportunity of using the first four switches of this type on the two light motor coaches of the Swiss Federal Railways. There are ten more being fitted in the light motor coaches for the Berne-Schwarzenburg line and other four for Diesel-mechanical motor coaches of the Swiss Federal Railways.

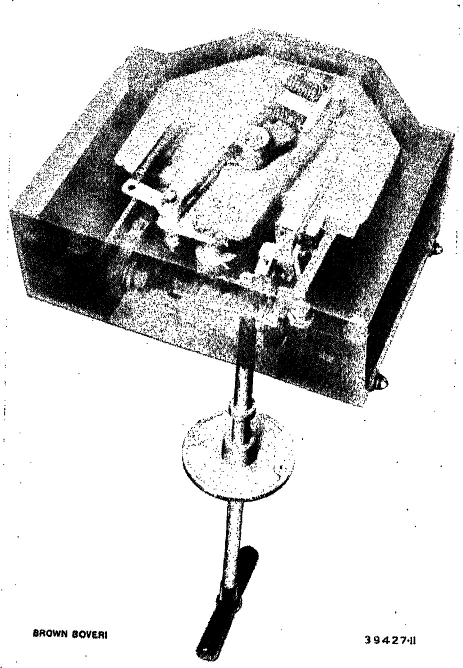


Fig. 138. – Automatic main-circuit breaker Type F4g1, for tramway coaches, for roof mounting. Rated voltage 750 V, rated current 200 A.

A new type of stronger simpler and cheaper *automatic main circuit breaker* has been brought out, for tramway coaches and for coaches on secondary lines; it is D. C.-operated. This breaker (Fig. 138) which has already been mentioned here, is intended to be mounted on the tramway roof and is closed, by hand, from inside the coach. The maximum tripping current can be set between 200 and 500 A. The breaker, which only weighs 20 kg is designed for 750 V and 250 A rated current and is able to stand up to a maximum rupturing current of 5500 A under a purely ohmic load and of 4000 A under inductive load (corresponding to 4 mH).

We had a first opportunity of delivering to the *Lille-Roubaix-Tourcoing tramway line* a D. C. cam controller of the well-known PN type combined to a Pieper type of oil-pressure servo-motor. The latter is controlled by a current relay which is to keep the starting acceleration and braking retardation constant within a range of 10 %. Each coach is equipped with a controller placed under the floor and governed by electric valve from two master controllers each having three positions. To keep down controller maintenance charges, the current is cut off by the line breaker and not by the controller itself when the controller is switched back.

In connection with the motors proper of electric vehicles, mention should be made of the electric equipment of a light motor coach for the *Oslo Tramway Co.* This is of similar design to the four-axle light motor coaches delivered two years ago to the Essen Tramways and which have been running since then; these units were developed and built by us together with the Waggon-Fabrik A.-G. Uerdingen. The coach has no bogie proper the motor itself acts as bogie frame; the motor is located on the longitudinal axis of the coach, between the two driving axles of a bogie and drives these axles over a conical gear with helicoidal gear wheels; it rests on three points on the two driving axles. Two of these points are formed by two rigid bracket bearings on one axle and the third by the gear bearing of the second axle. All the axle bearings and gear bearings are self-alining roller bearings. The whole bogie rotates on one pivot cast on the middle of the motor housing. The coach body is carried on cylindrical springs resting in cups which are bolted to the motor housing. The mechanical part of the bogie not belonging to the motor itself only weights about 1 ton, the body 5·8 t, so that the complete mechanical part of two bogies and the coach body is only about 7·8 t, in the present case. If 4·2 t are added for the electrical equipment, a total weight for the empty coach of about 12 t is reached. The tires of the driving wheels are sprung by rubber plates, as is the case with the Essen coaches, so that the motor does not rest straight on the tires.

As regards the electric equipments of locomotives, orders for which were given to us, mention may be made of six *locomotives of axle order* $2\,C_o — C_o\,2$, series 7501 for the Madrid-Villalba-Avila (120·5 km) and Villalba-Segovia (63 km) line sections for the *Spanish North Railway.* Six other locomotives of the same series with electric equipment according to our design are also being delivered by another Swiss firm. The Cia. Auxiliar de Ferrocarriles, Beasain, are general contractors and this company is building the mechanical equipment of all 12 locomotives. It should be said, here, that the new locomotives are of exactly the same Brown Boveri individual

axle drive type as the 12 units of the first batch, series 7201, ordered in 1927 from our Spanish Company and delivered in 1929. It is a splendid testimonial to the quality of our products that the same types, mechanical and electrical designs, the

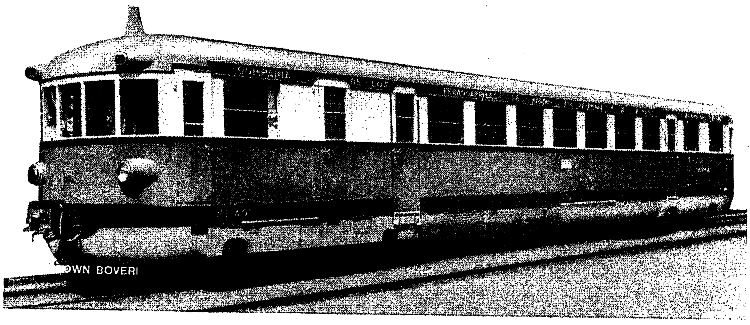


Fig. 139. — Diesel-electric motor coach of the Spanish MZA Railway.
Tare 43 t, 80 passengers seated, diameter of driving wheels 920 mm, highest speed 100 km/h, 1 Maybach Diesel engine 410 H. P. at 1400 r. p. m. Electric equipment with servo-field regulator control by Brown Boveri.

same individual axle drives of Brown Boveri design and, in general, the same electric equipment parts should have been specified for the new locomotives. At our suggestion, however, the one-hour rating was raised from 3240 H.P., 15,600 kg tractive effort on the wheel circumference at 56 km/h to 4200 H.P., 18,500 kg tractive effort on the wheel circumference at 61 km/h, the weight per locomotive remaining about the same. These units are again equipped for regenerative braking.

For a further locomotive for the *Norwegian State Railways* (line section Oslo Lilleström), the *Norsk Elektrisk & Brown Boveri* is to deliver the motors. *Tecnomasio Italiano Brown Boveri* have on hand seven more complete B_0-B_0-B_0 locomotives of group E 626, for the *Italian State Railways* and according to the drawings of the latter.

As regards equipments for rack and cable railways, mention can be made of two four-axle and one two-axle motor coaches for the *Sassi-Superga rack railway (Turin)*, service with which was begun on April 16th, 1935. There was also the equipment of the *aerial cable railway Beckenried-Klewenalp*, comprising the control set composed of a three-phase induction motor 70 kW continuous output at 1460 r.p.m., a D.C. generator of the same output with exciter, the D.C. winding motor for 60 kW, 440 V and 950 r.p.m. as well as all the apparatus for control. This railway was built in 1933 to Cantonal Government regulations and equipped with a 37-kW three-phase motor. The railway soon proved unequal to the increasing traffic and was rebuilt under Swiss Federal Government regulations, so as to be able to carry 20 passengers.

The *Basle Tramways* were the first, in Switzerland, to use our pantograph current collector equipped with carbon contact pieces, a most successful prevention of disturbance of neighbouring radio sets

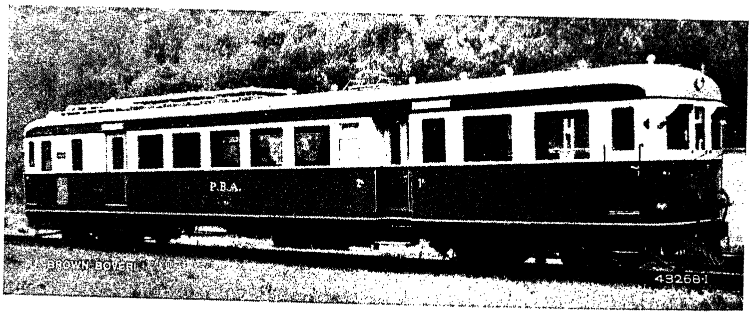


Fig. 140. — Diesel-electric motor coach of the Ferrocarril Provincial de Buenos Aires.
Tare 38·7 t, 62 passengers seated, diameter of driving wheels 850 mm, highest speed 80 km/h, 1 Sulzer Diesel engine 270 H. P. at 1100 r. p. m. Electric equipment with servo-field regulator control by Brown Boveri.

by the influence of the tram system. Many written testimonials go to show the great success of the innovation.

In the field of Diesel electric coaches, those of *the Madrid-Saragossa-Alicante (MZA) railway* were put into service successfully (Fig. 139). The first official trip took place on August 24th on the Beasain-San Sebastian section of the North Railway and on August 30th other trial runs were made on the Beasain-Vitoria-San Sebastian-Beasain line section. All runs were very satisfactory. On September 3rd, one coach ran from Beasain to Madrid and on September

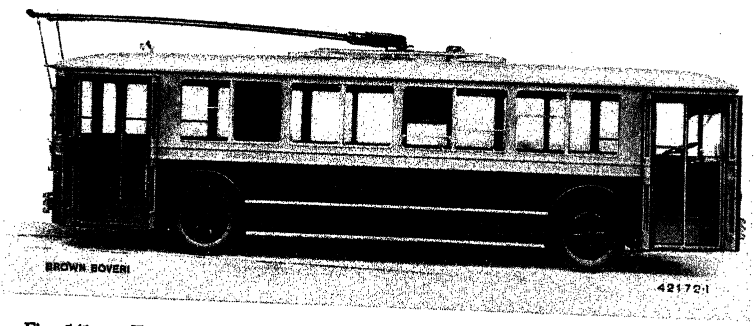


Fig. 141. — Trolley-bus of the Milan Tramways, for the Loreto—Bergamo route.

5th the official taking-over trips were run on the Madrid-Cuenca section. The 200-km line section with many grades was covered in 2 hours 9 minutes as against a guaranteed time of 2 hours 29 minutes. On the flat the speed of 100 km/h was attained in 137 s as against 150 s as guaranteed. Fuel consumption was 10 g/tkm referred to the line section Madrid-Toledo. The President of the Spanish Republic and the Minister of War took part in the inauguration ceremony. The absolutely smooth start was much admired and the smooth running at all speeds up to 100 km/h. No vibrations imputable to the Diesel engine were perceived in the coach.

A Diesel electric motor coach for the *Ferrocarril Provincial de Buenos Aires* (Fig. 140) ran a trial run before delivery on the Interlaken-Meiringen section of the Brünig Railway (Swiss Federal Railway system). Our electrical equipment of this coach and, especially, the servo field regulator control proved highly suitable.

Much work was done by us and our concessionary companies on the development of Diesel electric traction. By increasing the unit outputs by Brown Boveri Büchi charging it has been found possible to increase considerably the limits which formerly appeared maximum ones for this type of traction.

In June of this year, Tecnomasio Italiano Brown Boveri delivered a trolley bus (Fig. 141) to the Milan tramways for the Loreto-Dergano line section which has the following novel electrical characteristics:—

The coach has a motor developing 95 H.P. one-hour rating at 1680 r.p.m. and 550 V; it has two armature windings and two commutators. Each armature winding and two main poles can be connected, during starting, to the other armature winding and the other two main poles this in series and in parallel, so that it is possible to attain the same sequence of switching operations as in an ordinary tramway coach with two separate motors. The motor drives the rear bus axle through a cardan shaft and reduction gear with differential. Control is by a pneumatically regulated cam controller, the pneumatic device is remote-controlled electrically by a regulating controller placed before the driver and actuated by pedal. The switching of the cam controller at starting is regulated automatically by a current relay. As the driver depresses the pedal of the regulating controller further, he can get three settings of the current relay and thus adjust acceleration at starting and conditions on grades or in traffic. The cam controller has six series and four parallel positions. There is no electric braking. Results were so good that three similar equipments were ordered by the same clients from Tecnomasio Italiano Brown Boveri.

Finally, further successes can be reported on in the field of *hot-air heating of railway coaches.* The Swiss Federal Railways gave us a new order for 20 equipments to be put in new passenger coaches. Of the 20 equipments, 16 are for 1000 V, $16^2/_3$ cycles, four equipments are to be built for international heating voltages of 3000, 1500 V D.C. and 1000 V, $16^2/_3$ and 50 cycles. The change-over from one voltage to another is by hand, through the agency of a device so interlocked that faulty switching is impossible.

For these twenty coaches, the new train-heating couplings with mechanical interlock will be used throughout. The latter is so designed that it becomes ineffective as soon as the coach in question goes over to A.C. current. To this end, there are corresponding unlocking keys in the frontier stations. Thus the effect of the coupling interlock is limited to countries with the D.C. traction while in those using A.C. no interlocking of the coupling is carried out.

Our air-heating system was combined to the steam-heating system in an ingenious way, in an express passenger coach of the *Austrian State Railways.* As in the case of the last equipments delivered to the Swiss Federal Railways, the electric apparatus is designed for service at 1000 V, 50 and $16^2/_3$ cycles. The innovation in the present case is that a steam heater is bolted on to the electric heater, so that, when operating under steam, the heat is generated in the steam heater and carried into the coach by the same ventilating set as is used in electric heating. The advantage of this arrangement is that only heat ducts have to be laid inside the coach but no hot-steam pipes with valves and cocks.

B. VELOX LOCOMOTIVES.

The Velox steam generator is admirably adopted to the drive of locomotives and motor coaches, on account of the little space it takes up, its light weight, its rapidity in raising steam and exceptional adaptability to service requirements. The *Office Centrale d'Etudes et de Matériel* of the French Railways gave our French concessionaries, the *Compagnie Electro-Mécanique, Paris,* the first order, last year, for a Velox locomotive. To accommodate the equipment, an existing locomotive Type 2 C will be made over, the steam engines and driving gear being retained. As seen in Fig. 142, the Velox is placed vertically, as usual,

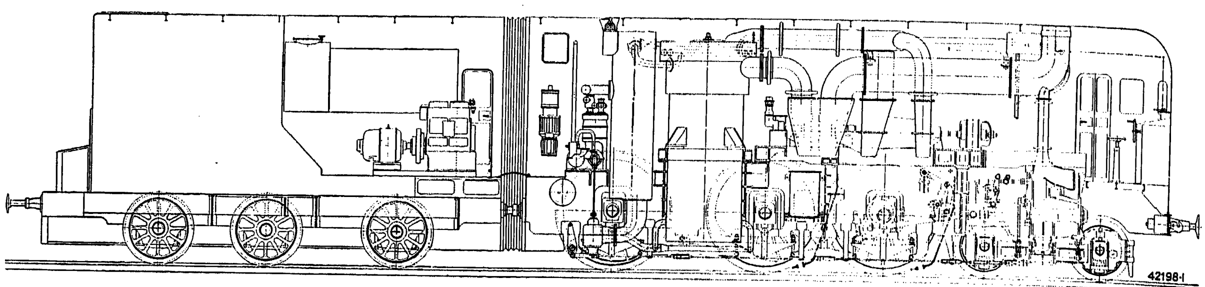


Fig. 142. — Velox locomotive built by our French concessionaries the Cie. Electro-Mécanique in Paris, for the Office Centrale d'Etudes et de Matériel of the French Railways.

An existing locomotive was made over. The steam engine and driving gear were retained. For this reason it was only possible to increase the output from 1600 to 2000 H. P. In new locomotives, the vertical arrangement of the Velox will allow of using individual axle drive, with small vertical high-speed steam engines. The difficulties encountered to-day and due to the big wheels and long connecting rods, will be eliminated, and any amount of power desired will be lodged in the locomotive.

between two driving axles, being anchored to a strong cast-steel foundation which reinforces the frame of the locomotive. The water separator is, also, vertical and placed beside the combustion chamber while the superheater coils are lodged in the evaporating tubes in the combustion chamber. The feed-water heater is of the water-tube type and suspended horizontally under the locomotive roof. The charging set with auxiliary turbine is above the frame of the locomotive. The pump set comprises the fuel, lubricating, governor-oil, feed and circulating pumps. The axles of the pumps are vertical in order to allow of placing the circulating pump as low as possible below the level of water in the Velox. The drive, however, is by a horizontal-shaft steam turbine through a gear. At starting the Velox, the charging and the pump sets are brought up to speed requisite to starting service, by starting electric motors. These get current from a D. C. petrol-driven generator, 30 kW, on the tender; as soon as the Velox begins to deliver steam, the auxiliary turbine takes over the drive, the starting motor of the charging set being automatically cut out while the starting motor of the pump set continues to run with the pumps, performing the functions of a lighting dynamos. The whole Velox plant is in an enclosed locomotive housing, and very easy of access. No continuous attendance is called for, as the Velox runs quite automatically. For this reason it was possible to place the driver's cab quite forward, without regard to the Velox proper or other machinery, the locomotive being controlled from the said cab in the usual way.

The output of this locomotive was raised from 1500 H.P. to 2000 H.P. by the change, and this is a not very big increase, a limit thereto being set by having to use the existing driving gear; the increase in question was reached by a moderate increase in the volume of steam produced and a small increase in live-steam pressure of from 16 to 20 kg/cm^2 abs. It must, however, be stressed here, in a general way, that the Velox allows of attaining any output desired on a locomotive while remaining within the restricted dimensions allowed for locomotives. We have made proposals for other railway managements for locomotives up to 7000 H.P. The design and vertical mounting of the Velox allow of using individual axle drive, so advantageous for high travelling speeds, this with small vertical and easily accessible high-speed steam engines. This solves all those difficulties encountered in modern locomotives due to the boiler layout and the long connecting rods.

Fig. 143 shows the drawings for a motor-coach train being studied for one of the European railways. It would carry 150 passengers, attain 130 km/h and be equipped with a 1000-H.P. Velox.

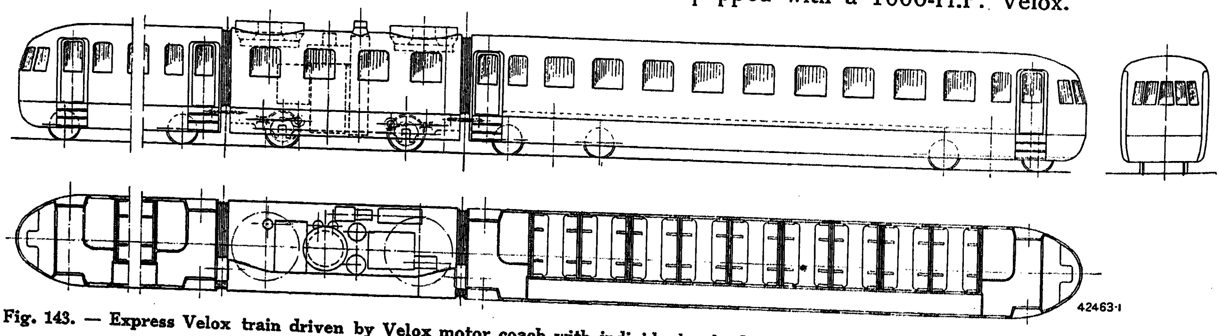


Fig. 143. — Express Velox train driven by Velox motor coach with individual axle drive through high-speed steam engines of Buchli type.

V. MARINE DRIVES.

A. VELOX PLANTS ON SHIPS.

We already reported on orders placed with our concessionaries by different *Admiralties* for Velox units. These units are running, to-day, most successfully, either on vessels or on test beds. We are not able, however, as will be readily understood, to give closer data on results.

The first order placed for a Velox steam generator for a passenger vessel, which is a *French liner*, is a matter of great importance for the development of the Velox itself, and, very probably, a factor of significance to the evolution of marine propulsion traffic, in general. This is the first step in a very wide field of application for the oil or gas-burning Velox. It also shows that the Velox has reached, to-day, that degree of reliability which allow it to be put into ships, this after the many proofs it has given of its value on land.

Unfortunately, we are not yet able to show an illustration of this first Velox marine plant, but the drawing in Fig. 144 will help to explain the layout.

The former boiler plant of this 21,000-t twin-screw steamer consisted of seven identical cylindrical boilers of each 7÷8 t/h of steam at 16 kg/cm² abs and 300° C and the machinery comprised two steam turbines of each about 5000 H. P. One of these boilers was taken out and replaced by a Velox for 35 t/h at 50 kg/cm² abs and 450° C. The machinery plant was increased by a first-stage turbine working at this higher pressure and a new low-pressure turbine in parallel with the old ones, to utilize the greater volume of steam available. These changes, practically, doubled the engine power, bringing it up to about 20,000 H.P. while the speed of the vessel was increased from 15÷16 to about 20 knots.

It is a significant fact that this alteration of the machinery plant, raising the output to double its former value, and the putting in of the Velox were carried out without affecting the usefulness of the old plant, practically at all. Although the reliability of the Velox in land stations had been amply proved, this demonstration of its adaptability to ship propulsion with a minimum of alteration to the former driving engines, will hardly fail to interest shipping

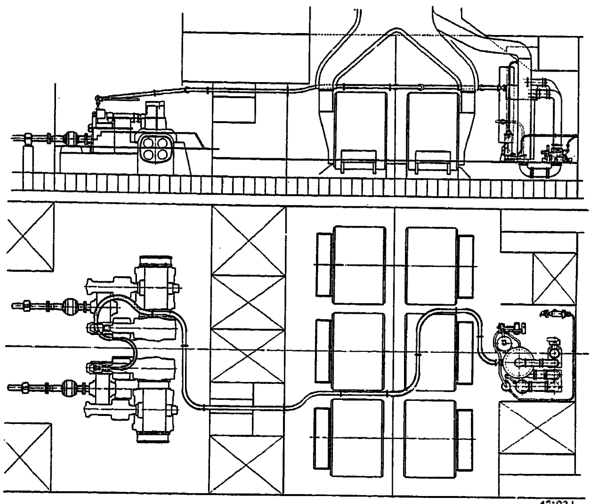


Fig. 144. — Plan of boiler and engine room of the first twin-screw passenger vessel, 21,000 t, equipped with a Velox steam generator. One of the seven existing steam boilers, each producing 9 t/h of steam at 13 kg/cm² abs and 300° C, was replaced by a Velox producing 35 t/h of steam at 50 kg/cm² abs and 450° C. Each of the two propulsion engines is now equipped with a first-stage steam turbine and a second low-pressure turbine, which raises the total power available from 10,000 H. P. to 20,000 H. P. Owing to the small space taken up by the Velox, the making-over work and enlargement of the machinery plant is possible without affecting the service efficiency of the old plant to any appreciable degree.

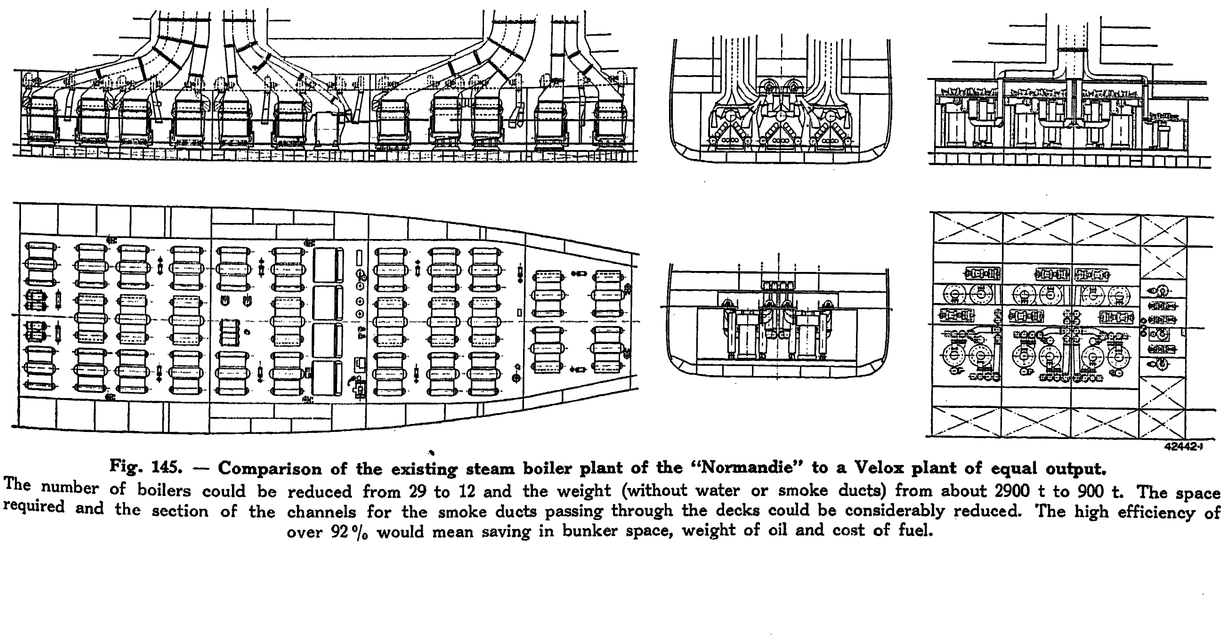


Fig. 145. — Comparison of the existing steam boiler plant of the "Normandie" to a Velox plant of equal output. The number of boilers could be reduced from 29 to 12 and the weight (without water or smoke ducts) from about 2900 t to 900 t. The space required and the section of the channels for the smoke ducts passing through the decks could be considerably reduced. The high efficiency of over 92 % would mean saving in bunker space, weight of oil and cost of fuel.

circles and should help the Velox to take footing in marine drives.

Fig. 145 shows the boiler plant of the "Normandie" as compared to a Velox plant of equal capacity. The economy which would be, thus, effected in valuable space and in weight is surprisingly great, the number of boilers being reduced from 29 to 12 and the weight thereof (without water or smoke ducts) from 2900 t to 900 t. One of the interesting points is the reduction in the size of the smoke ducts which take up very little room in the boiler room and in the shafts leading to the funnels.

In the case under consideration, the space taken up by ducts in the valuable area admiships, which might be used for other purposes, is reduced from 410 m^2 to about 55 m^2 section. Apart from saving in weight and in space in the boiler plant, attention should be given to the very high efficiency inherent to the Velox and the consequent saving in bunker area, oil fuel reserve, and cost of fuel. Although it must be admitted that the "Normandie" might be fitted with other types of high-power boilers taking up less space, it is, nevertheless, true that the example given shows what enormous possibilities lie before the Velox in marine plants.

The application of the Velox to *submarines* is an interesting chapter. In former years, steam boilers and steam engines were used for the surface propulsion of submarines but these were quickly superceded by the Diesel engine, which was much more economical to run. In the meantime, however, the steam turbine has been considerably improved both as regards its efficiency and the space it takes up and, to-day, the Velox is available, a steam generator which uses bunker oil as fuel, takes up a minimum of space, can be built for high outputs and operates at very good efficiencies, while being capable of providing a head of steam within a very few minutes from cold condition. A Velox for a plant of this type would be placed horizontally, as shown in Fig. 146 so that it finds space in vessels with a minimum of head room. The submarine propulsion machinery shown would develop about 2 × 5500 H.P. at 550 r.p.m. At submersion, the Velox would be extinguished but the main driving turbine goes on working until the Velox has emptied into the condenser and been cooled down to the desired temperature. The Velox and steam turbine should open the way to new developments and an increase in size of submarine craft.

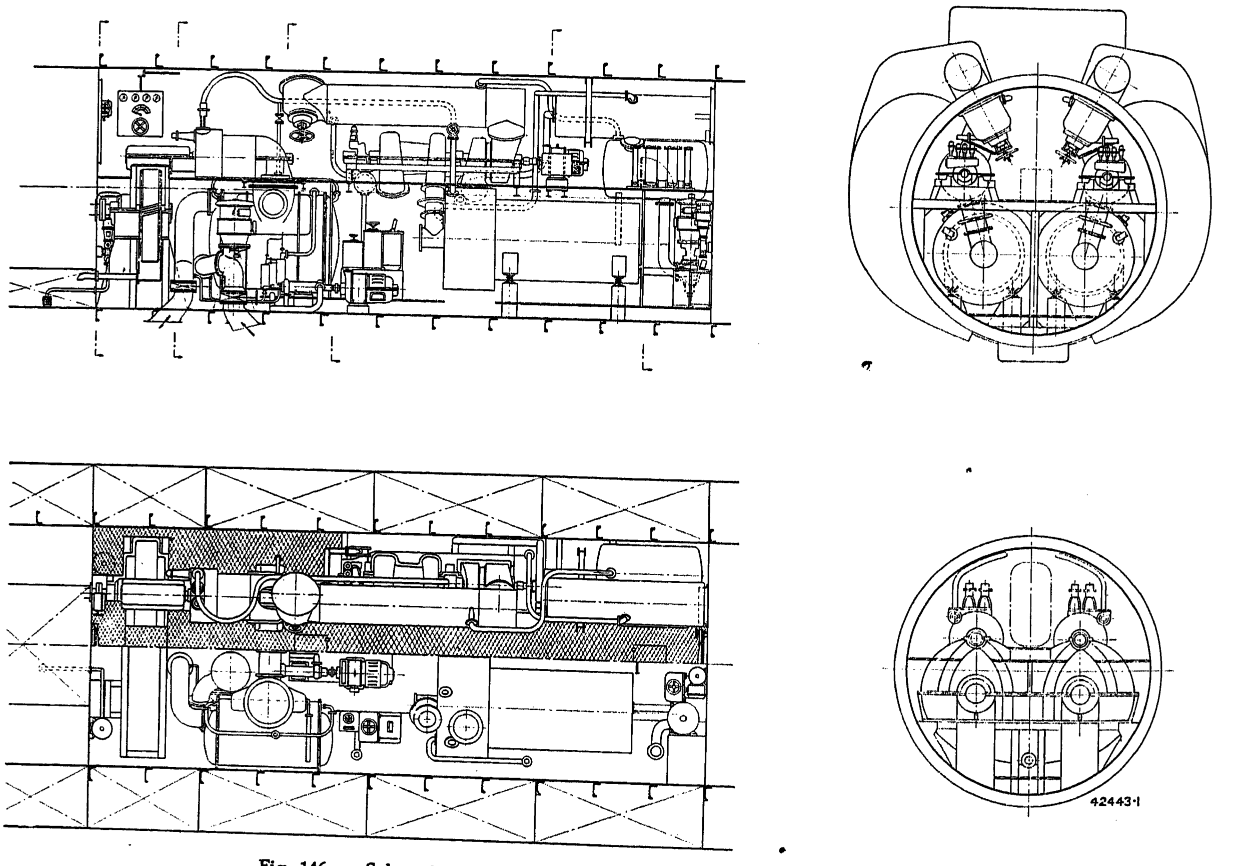


Fig. 146. — Submarine engine plant with 11,000 H. P. Velox steam generator.

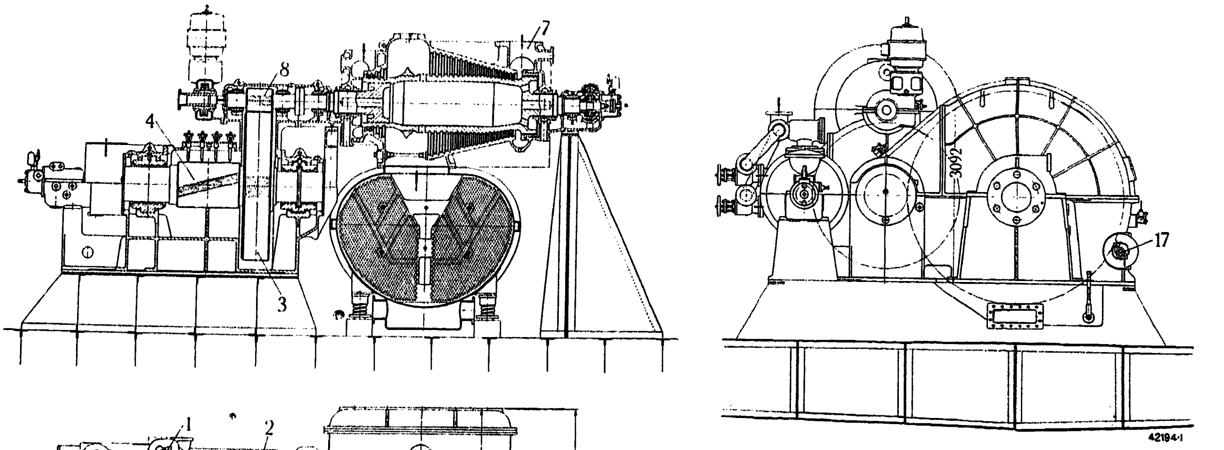
The small space taken up and low fuel consumption added to the rapidity with which steam can be got up, allow steam turbines to be used in submarines and, thus, open the way to new developments in this type of vessel.

B. MARINE TURBINES.

Fig. 147 gives a section of a marine turbloc built by our French concessionaries for the banana freighter "Katiola" of the Chargeurs Réunis Co.; a second similar plant having just been ordered for a sister ship. By compact arrangement of main and auxiliary engines, as well as of reduction gearing and condensing plant, considerable space and weight were saved and the efficiency improved. The two-cylinder turbine delivers up to 5300 H. P. on the propeller shaft. The high-pressure turbine 1 runs at 5150 r. p. m. and works through a double reduction gear 2—3—4—5 on the propeller shaft 6 running at 120 r. p. m. The low-pressure turbine 7 works at 2700 r. p. m. through pinion 8 on the intermediate shaft of the reduction gear, as well, and on the propeller shaft. The auxiliary machine set is composed of the cooling-water pump 9, an 80-kW D. C. generator 10, the condensate pump 11 and the governor-oil pump 12 and this set is, usually, driven by the propeller shaft through wheel 5, a pinion 13 and hydraulic coupling 14. When the speed of the vessel is very low and when the main engine is stopped, the auxiliary set is separated from the main engine and is, then, driven by the small auxiliary turbine 15 which, under ordinary conditions, runs empty in vacuum. The lubricating-oil pump and the governor-oil pump 12 as well as the condensate pump 11 are placed on two shafts of the reduction gear 16 of this auxiliary turbine. The vacuum pump is replaced by a steam ejector. The switching of the auxiliary machine set from the propeller shaft to the auxiliary-turbine drive is automatic and takes place when the speed of the main shaft has fallen to a little below the rated speed, this by the drop in pressure of the small governing-oil pump 17 of the hydraulic coupling.

When the speed of the main shaft rises again, the auxiliary set goes back automatically to main-shaft drive. The governing of the main turbine and of the change-over gear is built on the well-known Brown Boveri oil-pressure governing principle which we introduced to marine drives, some time ago, and which has given the most satisfactory results in the mercantile marine as well as in warships.

Fig. 148 shows the diagrammatic layout of the *Brown Boveri oil-pressure governing system for marine turbine plants* with Velox steam generators. The working of this governing system will be better understood from the following example:— as a result of an order received, the engineer places the engine governing gear to a higher power position, by rotating handwheel 13 a to the right, or else the bridge officer does so, himself, from the bridge by means of drive 13 b. By rotation of the governing spindle the



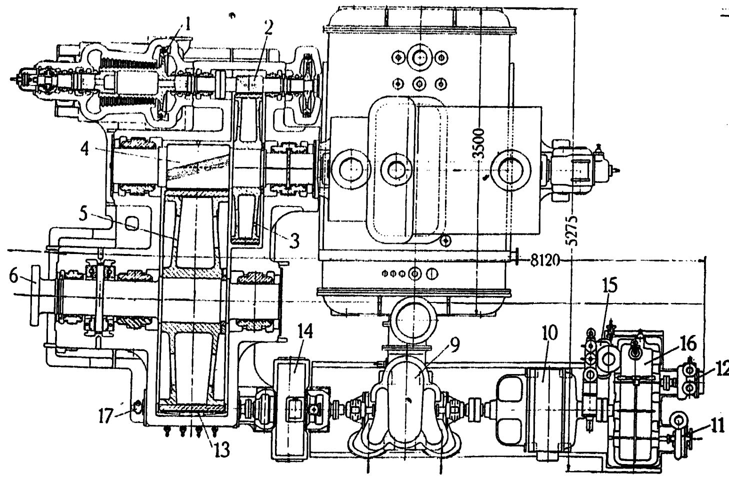


Fig. 147. — Section of a marine turbloc placed on the French banana freighter "Katiola" belonging to the Chargeurs Réunis Co., 5300 H. P., propeller speed 120 r. p. m.

Turbine, reduction gear and condenser are built close together. The auxiliary set is driven from the main engine through a hydraulic coupling, under ordinary conditions while, at low speeds and when in port, the auxiliary set and lighting dynamo are driven by an auxiliary steam turbine, which runs in vacuum when the vessel is at its usual travelling speed.

"ahead" oil slit in the governing apparatus is somewhat closed, the governing oil is dammed up with the result that the pressure of oil in the servo motor of the governing valve 15 of the "ahead" turbine 1 rises the valve is opened further and the output of the turbine rises. The increased steam consumption brings down the head of steam in the Velox, causes a lowering movement of the spindle and a closing of the oil-escape valve in the pressure regulator 18b. The oil is now dammed up, here, as well with the result that the piston of the fuel servo-motor 18a opens the fuel valve further. The fuel-measuring nozzle causes a bigger drop in pressure and causes the spindle of the mixture governor 20b to move downwards. Here, as well, the oil valve closes, the oil pressure rises and, in this case, it opens governing valve 20a of the additional auxiliary steam turbine. The charging set is accelerated, blower 6 delivers more air, to burn the greater quantity of fuel. This increased air flow is measured in the air nozzle and the big pressure difference occasioned here reacts on the mixture regulator until the influences of fuel and air compensate one another. Thus, for each load setting, the fuel and air quantities are automatically adjusted. A reverse rotation of the governing gear, to the "stop" position, causes the oil pressure in the "ahead" governing apparatus to fall, the oil valves close of themselves. The fuel-oil feed now goes down to the no-load quantity and the charging set to the corresponding speed; thus the boiler remains in service during the stop. The position "astern" on the governing gear causes valve 16 of the "astern" turbine 2 to be connected up. When the maximum admissible speed of the turbine is exceeded, the safety governor 26 operates, instantaneously causing the oil under the main closing valve 14 of the main turbine to flow off and the quick-closing valve to close. The feed valve 19a is so opened by the water-level regulator 19b that there is always a definite quantity of water in the Velox, automatically maintained. The marine-turbine oil-governing gear is easy to supervise, simple to manipulate and very reliable. It is easy to so design it that it can be operated from the bridge, so the engine-room operators need not intervene during manœuvring. We think there is a great future for this governing system on ships.

C. MARINE AUXILIARIES AND THEIR DRIVES.

The drive of the numerous auxiliaries of land and marine machinery plants has always been a difficult problem to solve, because it is an expensive matter, is frequently wasteful and because the reliability of the main engines depends on the behaviour of the auxiliaries and their drives. It is customary, in land stations, to drive the auxiliaries individually by electric motors, as is done in big machine tools and in workshops where individual drive of the different parts proved to be the simplest and most advantageous solution. This type of drive for auxiliaries is not, however, absolutely reliable, as the supply of current is depen-

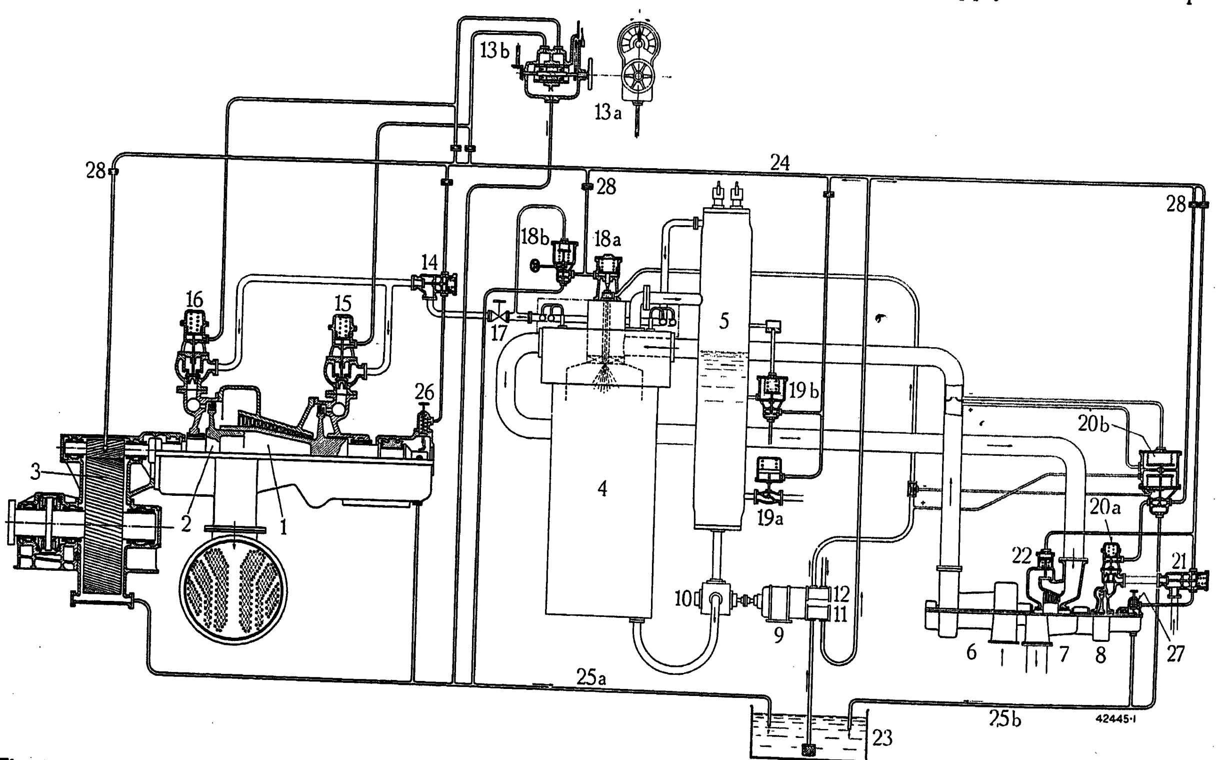


Fig. 148. — Diagrammatic layout of the Brown Boveri oil governing gear of a marine plant, composed of a Velox steam generator with auxiliary as well as an "ahead" and "reverse" turbine.

By moving the main governing valve 13, which can be done by the engineer or bridge officer, all the necessary regulating operations are produced on the Velox, auxiliaries and main turbine. This governing system is very easy to supervise; it is reliable and very simple to actuate. It has been used successfully on warships and has a sure future in marine engine design in general.

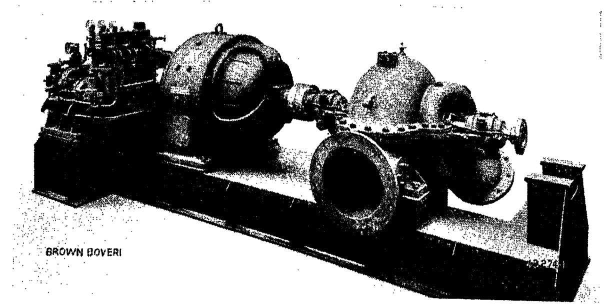


Fig. 149. — View of auxiliary set for a marine turbine plant, 5300 H.P., for the freighter Katiola.

Under ordinary conditions, this set is driven through a hydraulic coupling (not shown) and at low speeds or in port by an auxiliary turbine. The set comprises the cooling-water pump, an 80-kW D. C. generator, the condensate pump and the governing-oil pump. A steam ejector replaces the vacuum pump.

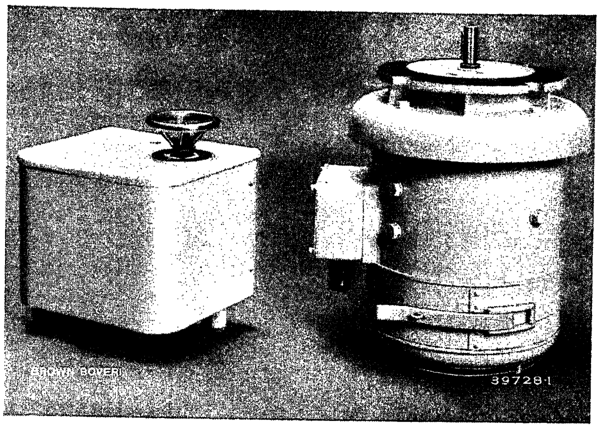


Fig. 151. — D. C. motor with starting winding for pump drive on a submarine, along with all the switching apparatus belonging thereto.

dent on the distribution network which is itself fed from the main plant. Trouble on this distribution system from some external cause, from other machines, or from switchgear etc. can endanger the supply of the auxiliaries and, therewith, the drive of the main engines. For this reason spare generators and spare auxiliary distribution systems were introduced the duty of which is to take over the power supply to the auxiliaries, immediately and automatically, when the necessity arises. In modern marine plants, however, electricity is so universally used for lighting, ventilating, wireless, cranes, winches, etc., during travelling, and in harbours and while in dock and the plants are so generously provided with spares that there is no danger whatever in driving the auxiliaries of the main units by electricity. On small vessels, the electric power can be delivered from a D. C. generator coupled to the main engine which increases economy in service and reliability, during running, while, in harbour, the current for auxiliaries and lighting can be supplied by an auxiliary turbo or Diesel generator. Of course, straight steam-turbine drive of auxiliaries or a combined drive by electric-motor with automatic substitution of a spare turbine for emergency is a very reliable solution indeed. In such cases the auxiliaries are grouped together, despite the longer piping entailed, this so as to have only one auxiliary turbine and to save expense of the plant itself, as well as running charges, Fig. 18.

A very reliable solution is to drive the auxiliaries direct, through reduction gears, from the main turbine, just as lubricating pumps have always been driven. This solution, as well, has as a consequence that the position of the auxiliaries is not rational but a grouped one dependent on the common drive. For marine auxiliary-machines working at varying speeds and which must run in harbour, special measures must be taken, if this last solution is adopted. The solution just mentioned for the "Katiola" in which the auxiliaries are driven from the main engine, at high speeds of the vessel and by special turbine or motors at other speeds or during stoppages, can be applied. Fig. 149 shows auxiliaries without the hydraulic coupling.

Our Marine Department is always ready to advise on or to study the best possible solution for the various problems in the field of the drive of marine auxiliaries.

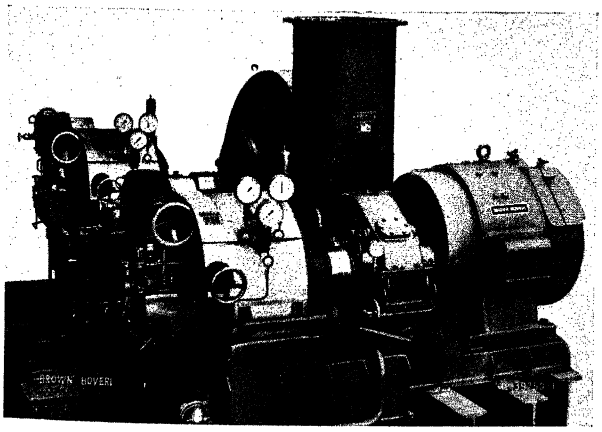


Fig. 150. — Auxiliary set of the motor ship "Vulcania".

The set comprises a scavenging blower driven by steam turbine and used for the main Diesel engines and also a D. C. dynamo driven by a second turbine.

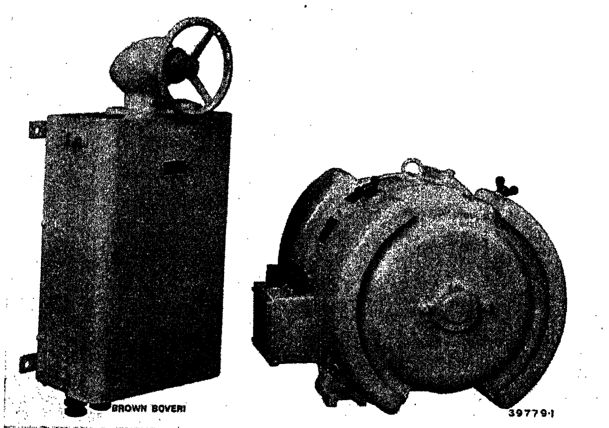


Fig. 152. — Splash-water proof D. C. motor with the splash-water proof controller belonging thereto.

Fig. 150 shows a set of marine auxiliaries for the motor ship "Vulcania". The set includes a scavenging blower driven by a steam turbine and used to scavenge the main Diesel engines, for which purpose 1200 m^3/min of air is required; the set also includes a D. C. dynamo driven by a second independent steam turbine. Both sets are on a common bedplate and utilize the same oil reservoir.

For the motor ship "Saturnia" we delivered three scavenging blowers, according to Fig. 153, built to deliver each 1800 m^3/min of air and which are the biggest units of their kind built up to date. The

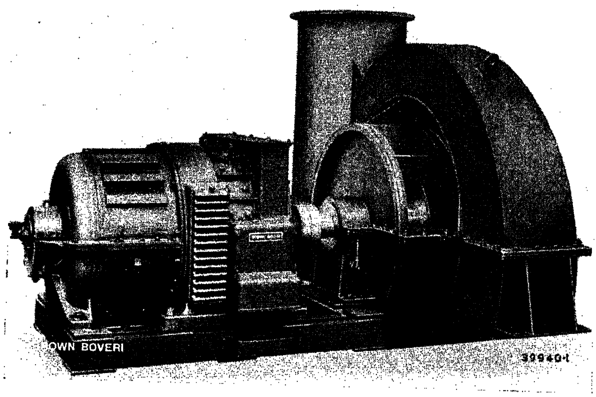


Fig. 153. — One of three scavenging blowers for M.S. "Saturnia" delivering 1800 m³ of air per min.

blowers are driven by D. C. turbo-motors each of 700 kW at 220 V and 2470 r. p. m.

The three scavenging blowers delivered for the motor ship Saturnia, are driven by D. C. turbo-motors of a very compact design. The motor has a cast aluminium housing with forged iron yoke rings and ball bearings lodged therein. These motors imposed severe conditions on the designer as regards commutation, on account of the output and speed. All difficulties were successfully met, thanks to our experience in the field of D. C. turbo-machines and owing to special winding and commutator designs applied here.

Apart from a great number of *ship-lighting plants* in the form of turbo-lighting sets and Helux equipments, we and our concessionary companies have delivered or have building about 100 turbo or Diesel dynamos of a total of more than 10,000 kW. More than 50 automatic quick-acting regulators were delivered to warships and the mercantile marine, and it may be said here that this regulator has proved fully its adaptability to service conditions in warships despite the concussions due to gun fire. In our last report mention was made of marine wireless transmission stations of small output, for which regulator Type J 1/1 was used for a frequency range of 40 to 90 cycles for voltage regulation practically independent of frequency. It is used where the A. C. radio generator is driven by a D. C. motor fed from auxiliary sources at very fluctuating voltages.

Apart from numerous motors delivered by us, last year, for the drive of marine auxiliaries, we would mention our *splash-water proof motors* of light and compact design, suitable *to submarine service* (Figs. 151 and 152). Although these motors are thoroughly protected against the ingress of water, they are very efficiently cooled which allowed of reducing weight and dimensions to a minimum. These motors have auxiliary compound and starting winding. The starting gear is also specially designed to be small and light, it is built for semi-automatic starting in such a way that the motor is first connected to the supply voltage through its starting winding and a separate starting resistance in series with it, after which the starting resistance, and then the starting winding, are cut out, automatically. Special measures were taken to attain as silent running as possible despite high speed and very efficient cooling, because this is a valuable asset for certain fields of application. We made a special study of these motors last year, and are in a position, to-day to deliver splash-proof motors of very compact design and of light weight, for speeds up to 4000 r. p. m.

D. ELECTRIC SHIP PROPULSION.

We reported last year on the electric drives delivered by us for two Finnish coastal-defence battleship, for a Norwegian mine layer and for the saloon paddle vessel "Genève". Further a fairly detailed article on our ship-propulsion equipments appeared in The Brown Boveri Review of September and November 1935, to which we would refer readers for more details.

We had the opportunity, in the course of last year, of further developing our submarine electric equipments and made very considerable progress in reducing the weights of driving motors, while bettering the efficiency thereof.

One of our concessionary companies got an order, last year, for a Diesel-electric marine plant of 6800 H.P. for a single-shaft tramp ship. The plant is based on our three-phase transmission system described here, already[1]. The propeller double motor is a synchronous one with cage winding for starting up asynchronously and for manœuvring; it is supplied by three Diesel-generator sets. There are also converter sets for excitation and an auxiliary Diesel generator for harbour service. This is the first big Diesel-electric A.C. ship-propulsion plant in the world.

(MS 970 I/II.) *P. Faber. K. Sachs. (Mo.).*

[1] See The Brown Boveri Review, 1932, No. 5, page 148.

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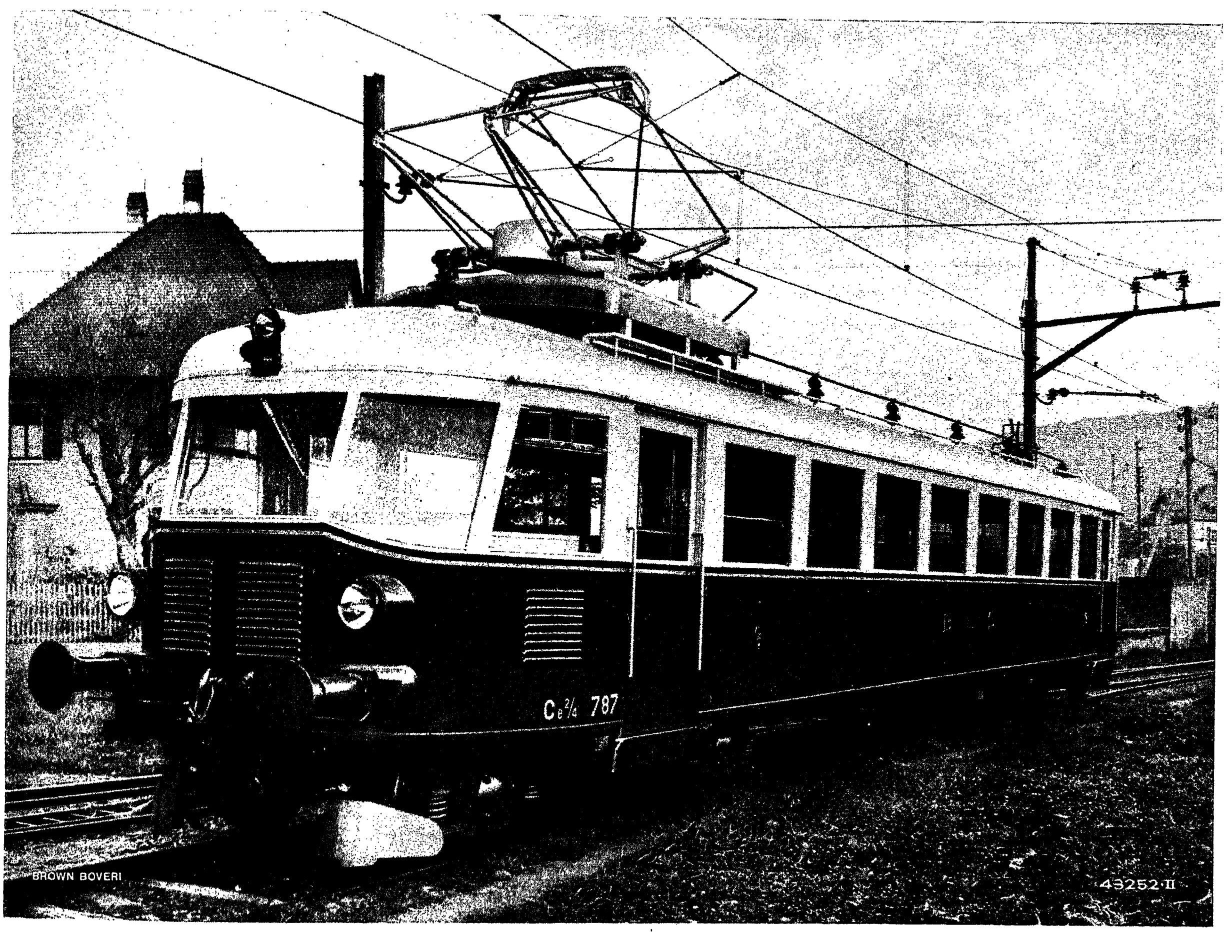
VOL. XXIII MARCH, 1936 No. 3

THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



SINGLE-PHASE LIGHT MOTOR COACH Ce $^{2}/_{4}$ No. 787 OF THE BERNER ALPENBAHN GESELLSCHAFT (BLS), BERNE.
Supply voltage 15,000 V, 16$^{2}/_{3}$ cycles, built by Brown, Boveri & Co. Ltd., Baden and the Schweizerische Industriegesellschaft, Neuhausen.

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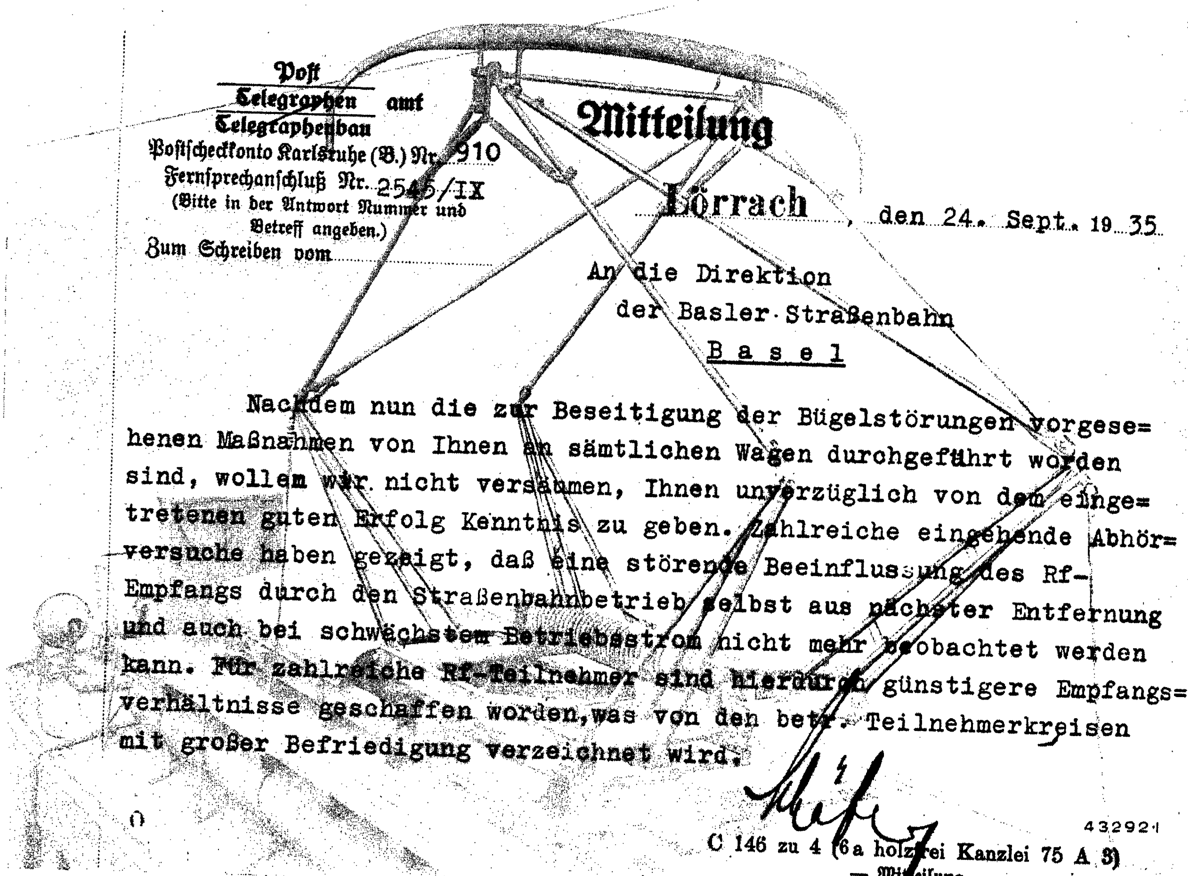
BROWN BOVERI
PANTOGRAPH CURRENT COLLECTOR



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Zum Schreiben vom

Mitteilung

Lörrach, den 24. Sept. 19 35

An die Direktion
der Basler Straßenbahn
Basel

Nachdem nun die zur Beseitigung der Bügelstörungen vorgesehenen Maßnahmen von Ihnen an sämtlichen Wagen durchgeführt worden sind, wollen wir nicht versäumen, Ihnen unverzüglich von dem eingetretenen guten Erfolg Kenntnis zu geben. Zahlreiche eingehende Abhörversuche haben gezeigt, daß eine störende Beeinflussung des Rf-Empfangs durch den Straßenbahnbetrieb selbst aus nächster Entfernung und auch bei schwächstem Betriebsstrom nicht mehr beobachtet werden kann. Für zahlreiche Rf-Teilnehmer sind hierdurch günstigere Empfangsverhältnisse geschaffen worden, was von den betr. Teilnehmerkreisen mit großer Befriedigung verzeichnet wird.

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— Mitteilung —

The Basle Tramways were the first tramway service in Switzerland to introduce, on all their coaches, the

Brown Boveri pantograph current collectors with carbon contact pieces
(design protected by patent)

As a radio interference suppression measure this has proved a brilliant success, as is conclusively shown by the letter, reproduced below, from the Lörrach Post Office.

Post Office

Lörrach, Sept. 24th, 1935.

To the Management of the Basle Tramways,

Basle

"Now that the measures you took to eliminate disturbances due to bow current collectors have been completed on all your coaches, we desire to inform you, without delay, of the excellent results therof. Numerous listening-in tests have proved that disturbances are no longer perceptible even with receiver sets located close to the tramway line and operating under weak currents. This means that advantageous receiving conditions have been created for numerous wireless receiver-set owners and the latter have expressed their great satisfaction with the results."

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIII MARCH, 1936 No. 3

The Brown Boveri Review is issued monthly. — Reproduction of articles or illustrations is permitted subject to full acknowledgment.

VISIT TO THE BROWN BOVERI WORKS COMBINED WITH DEMONSTRATIONS AND TESTS ON SEVERAL NEW DESIGNS.

Decimal index 659. 151 : 621. 3.

KNOWING the importance to a manufacturing firm of keeping in touch with circles interested in their products, Brown Boveri started, years ago, to give periodic demonstrations and explanations of their new designs to clients, representatives of technical institutions, the Press, etc. Such a demonstration took place on November 20th, 1935 and a short description thereof is given below.

The new designs evolved, recently, can be divided under the following headings:—

	Site of demonstration:—
Network operation Network regulation Network protection	(a) High-power testing plant (b) Apparatus testing department (c) Transformer testing department (d) Mutator testing department
Consumption of energy	(e) Machine testing department (f) Steam-turbine testing department.

a) *High-power testing plant.*— Although, in recent years, it has again been possible to improve very considerably the reliability of *oil circuit breakers*, the fact still remains that with this kind of circuit breaker the medium for extinguishing the arc, that is the oil, is subjected to very high temperatures, caused by the arc and so the desire to eliminate the oil filling entirely persists. Therefore, circuit breakers without any oil or using only a limited quantity of oil have been developed. *Water circuit breakers* having a high degree of reliability can be built for working voltages up to about 30 kV. Further development for higher voltages is, however, limited by technical difficulties with regard to the insulation. The experimental results obtained with the water circuit breakers proved useful for the development of circuit breakers *using a limited quantity of oil*, that is, the *"Convector" circuit breaker* and *oil circuit breakers* with *"Convectors"*, the former being built for the highest working voltages required. The latest development is, however, *the air-blast high-speed circuit breaker*, the forerunner of which was already built and tested by the firm in 1922 and found to be effective, but, unfortunately, owing to the lack of a high-power testing plant could not be further developed at that time. The new air-blast high-speed circuit breaker, which is, without doubt, the circuit breaker of the future, operates with a working pressure which cannot exceed a certain value when opening under short-circuit conditions; the switching element consists of an arcing contact controlled by compressed air and a visible, disconnecting (knife) contact. This latter is of considerable advantage to the operating staff. The arcing contact is very light and is moved at high speed by the compressed air so that an exceptionally rapid interruption of the are occurs and hence the name of air-blast high-speed circuit breaker. With three-pole circuit breakers, the three poles are served by a single air valve which results in the apparatus being as air-tight as possible. The compressed air serves as a power accumulator and at the same time acts as the operating medium and as a clean and cheap extinguishing medium for the arc.

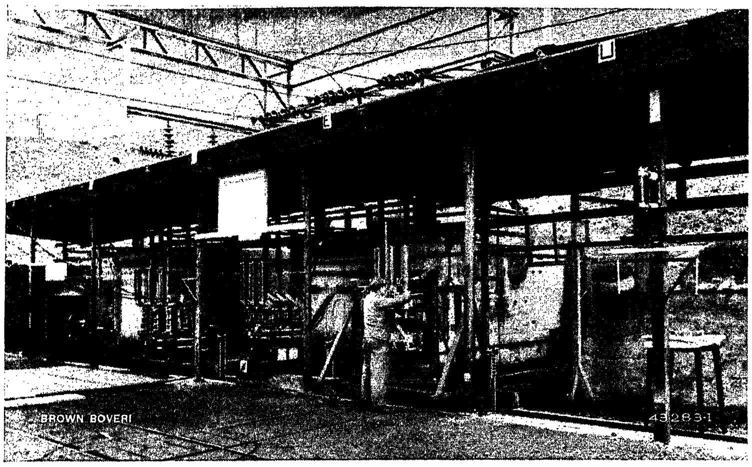


Fig. 1. — Air-blast high-speed circuit breaker and high-voltage fuses on the test bed. From U to the left air-blast high-speed circuit breaker, below U high-voltage fuses.

On the occasion of the visit on the 20th November most types of circuit breakers at present being built were on view in the high-power testing department. Naturally, chief attention was devoted to the air-blast

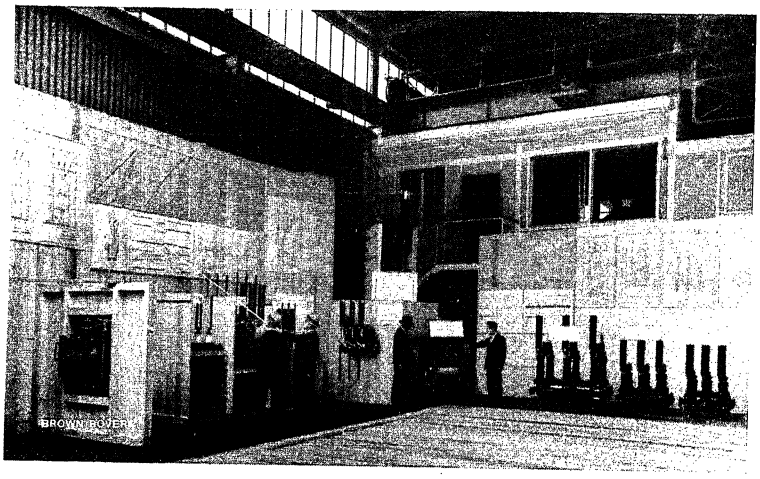


Fig. 2. — View of part of the circuit breaker exhibition.
Methods of mounting, diagrams and curves from research work on air-blast arc extinction.

high-speed circuit breaker. The considerable research work done on air-blast extinction was referred to and also the principle of this new circuit breaker explained by means of diagrams, oscillograms and sectional drawings (Fig. 2). The various *ways of mounting* the circuit breakers and especially the possibility of replacing older circuit breakers in existing plants by the new air-blast high-speed circuit breaker were demonstrated by typical examples. Fig. 2, left front, shows how with an air-blast high-speed circuit breaker the control side of the breaker can be separated from the high-voltage side by means of a protecting partition.

Air-blast circuit breakers for 11 kV up to 400,000 kVA breaking capacity were shown in operation on the test bed of the high-voltage test plant (Fig. 1 from U to the left). In the early days of high-voltage development, so-called *isolating switches* were built for open interruption in air. By means of tests with such a circuit breaker it was demonstrated that the arc could no longer be extinguished even with a comparatively small load, whilst a 50-kV air-blast high-speed circuit breaker opened and closed on 20 times the short-circuit capacity exceeding 500,000 kVA in a really elegant manner without any externally visible signs of distress. The following table shows the improvement in operating time when compared with the old circuit breakers:—

Operating times and arc duration for three-pole high-voltage circuit breakers 6·4—37 kV.

Type of circuit breaker	Built in year	Opening time	Arc duration
		s	s
Oil circuit breaker with solenoid contacts Type AV	1925	0·25	0·08
Oil circuit breaker with wedge contacts Types O and OV	1929	0·1	0·05
Water circuit breaker Type U	1932	0·1	0·03
Air blast high-speed circuit breaker Type D. . . .	1935	0·05	0·01

The above times are maximum values and may be considerably shorter, depending upon the working voltage.

New *high-voltage fuses* were also demonstrated by means of tests. (Fig. 1, below U on the right is a fuse and, underneath, two fusible elements.) These fuses function extremely rapidly. The short-circuit current is already interrupted when it first starts to rise during its formation. They are particularly suitable for *small* consumer stations, whilst for more important services it is perhaps preferable to employ a power circuit breaker.

(b) *Apparatus testing department.*— Amongst the *high-voltage apparatus* on view there was also a *three-pole single-tank oil circuit breaker* equipped with "Convectors" for 110 kV, 400 A, 750,000 kVA rupturing capacity, and a *three-phase high-current oil circuit breaker* for 1500 V, 4000 A, the main contacts of which are *in air* and only the auxiliary contacts (solenoids) *in oil.*

Distance relays (Fig. 3, item 1) in the well-known *three-pole construc-*

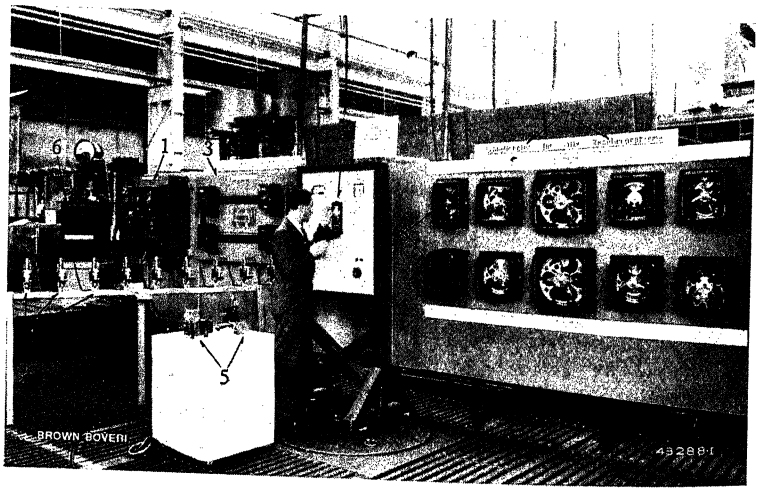


Fig. 3. — Relay and regulator exhibition.

1. Distance relay.
2. Testing apparatus for distance relays.
3. Earth fault directional relay.
4. Primary relay.
6. Low-voltage regulating transformer with control relay.
7. Quick-acting regulator for all regulation problems.
8. Single-contact sector regulator.

tion for overhead lines were shown together with the accompanying *testing devices* (Fig. 3, item 2). Due to the development of the new *single-relay connection* it is also possible to protect networks for lower voltages with distance relays, very cheaply.

Directional earth-fault testing relays (Fig. 3, item 3) were demonstrated on a model ring network; they form a valuable practical addition, especially for the operation of lines equipped with extinguishing coils. They indicate the defective part of the section so that the complicated disconnection of line sections becomes unnecessary.

Series relay Type HB 4 is a new design of relay Type H 4 which has been known for over 20 years all over the world. The most important improvements are, besides various innovations to facilitate attendance during service, high invulnerability to short-circuit currents and precise time setting; this latter feature was very clearly demonstrated by means of ten relays connected in series and graduated in steps of 0·1 s only. (Fig. 3, item 4.)

A new construction which attracted particular attention was the *current-indicating secondary relay Type S* (Fig. 3, item 5) which at the same time acts as an ammeter. The features of this new apparatus are the ready accessibility of all important parts, possibility of testing during service, maximum precision of time settings, low power consumption, and widest possible range of settings. Due to these excellent features, relay Type S will soon find favour with supply engineers.

The tapless *low-voltage network regulating transformer* (Fig. 3, item 6) which can be built and used for voltages up to 500 V in place of an induction regulator, enables the voltage to be regulated at the *point of consumption*. The supply of electric power at a *constant voltage* at the consumers' end is a condition which should be fulfilled to-day, as far as possible by all supply companies, so that machines, apparatus and lamps may be used rationally. This purpose is served by the low-voltage network regulating transformer which is, in principle, an auto-transformer on the spirally-wound regulating winding of which a current collector slides. This is actuated automatically by a voltage relay and a control motor. By this means an entirely *smooth* voltage regulation is possible, the accuracy of the regulation being $\pm$ 0·5 %. The value of the regulated voltage required is directly adjusted for on the aforementioned relay. The normal range of regulation is $\pm$ 8·5 %. The model on view belongs to the smallest standard type and is capable of dealing with a capacity of 30 kVA at 380 V. Types are also built for 100, 200 and 400 kVA.

The fact that *quick-acting regulators* are built for all *regulation problems* which occur, was convincingly demonstrated by the regulator collection, as shown in Fig. 3, item 7. The *standard design* of the well-known Brown Boveri quick-acting regulator has had various important improvements made on it. Besides making improvements which serve to facilitate its operation and increase the number of regulating steps and the accuracy of response, the *regulating speed* was considerably increased and thus this apparatus, the fundamental principle of which has often been copied without the same quality of instrument being attained, is able to comply, in every respect, with the demands made upon it by modern science and will continue to maintain its leading position in the markets of the world. The need for automatic voltage regulation for *small* as well as *large generators* has been satisfied, for some considerable time ahead, by the construction of a *single-sector small regulator* (Fig. 3, item 8) and a *high-power voltage regulator* (Fig. 4, item 1). These new types are characterized by the excellent qualities of the similar instruments already so well known.

Great interest was evoked by a *frequency-regulating device* which is intended to regulate the *frequency* and *power* for the usual parallel operation of power stations and complete networks. This apparatus is constructed from well-tried component parts of the Brown Boveri quick-acting regulator and enables a variety of regulating problems to be solved, because with this apparatus *power* and *frequency charts* to be adhered to can be automatically maintained as required. Such an instrument (Fig. 4, items 1 and 2) was demonstrated on the test bed.

The *paralleling apparatus* (Fig. 4, item 3) combined with an air-blast high-speed circuit breaker showed plainly the *saving in operating time* achieved by the latter, the circuit breaker closing in a minimum of time on a very short angular lead.

A *67-kV neutral point on-load tap-changing switch* for large transformers also falls under the heading of voltage regulation. The principle used here is the same as that for the well-known on-load tap-changing switch previously built by Brown Boveri. The new regulating device consists of two parts, the *load switch* in air and *tap selector* in oil. A new feature is that there is a *fine-regulating* and a *coarse-regulating selector*, so that a considerably increased regulating range combined with fine regulation is obtained. The contacts of the load switch in air, can be easily inspected. This apparatus is built with a view to maximum reliability and for 11 to 150 kV for direct installation in the transformer tank. The switch is actuated by a spring-operated mechanism of latest design mounted on the transformer tank.

A *portable oil-testing apparatus* for max. 70 kV, in a compact and practical form, was also on view.

A modern *automatic coach switch* for direct-current tramways and overland railways was demon-

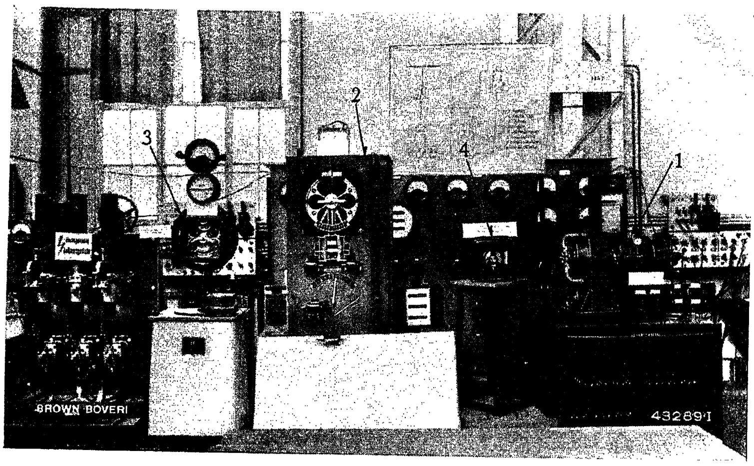


Fig. 4. — Frequency regulating device.
1. High-power regulator. 2. Frequency regulator. 3. Synchronizing apparatus.

strated for 1000 V, 400 A and about 4000 A short-circuit current. This apparatus forms a very valuable safety device for *narrow-gauge railways*. The *quick-acting switch*, which was shown, is used for *stationary* plants and standard-gauge D. C. locomotives etc. In addition there was also a series of *controllers* for tramways, hoisting mechanisms, etc., on view.

(c) *Transformer testing department.*— Great interest was displayed by all visitors in the tests concerning the *protection of electric installations against lightning discharges.* Since the cathode-ray oscillograph has provided the test engineer with the means of measuring times less than one millionth of a second, research work in this field has received a powerful impetus. *Direct lightning discharges* have been recognized as providing the greatest danger to the operation of transmission systems. The more frequent *indirect lightning strokes* only cause a dangerous overvoltage in networks of up to about 40 kV. The energy thus released continues as *surges* in the network and affects the windings of the transformers, machines and apparatus. A certain amount of protection can be obtained by *graduating the insulation strength* of the various parts of the plant so that the external flash-overs occur on parts likely to suffer little damager. Instead of allowing the flash-over to occur as aforementioned the surge energy can be discharged to earth by means of a *Resorbit lightning arrestor.*

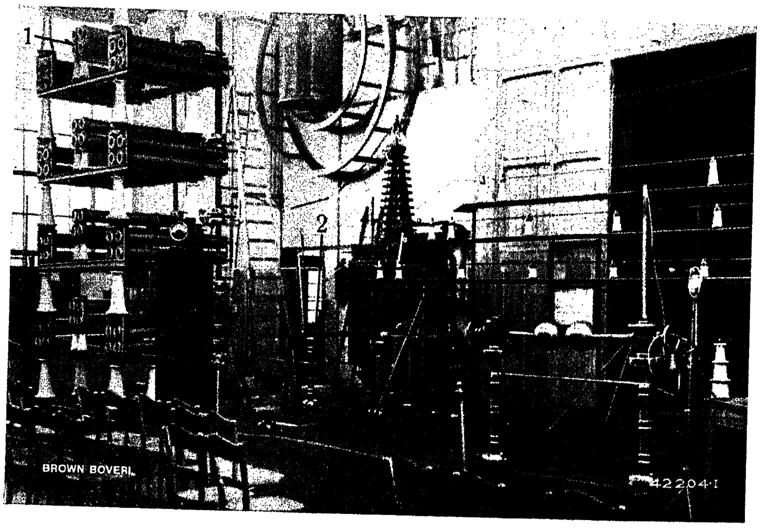


Fig. 5. — Model network.
1. Lightning generator.
2. Needle mutator.
3. Conductors in the plant, with supporting insulators.

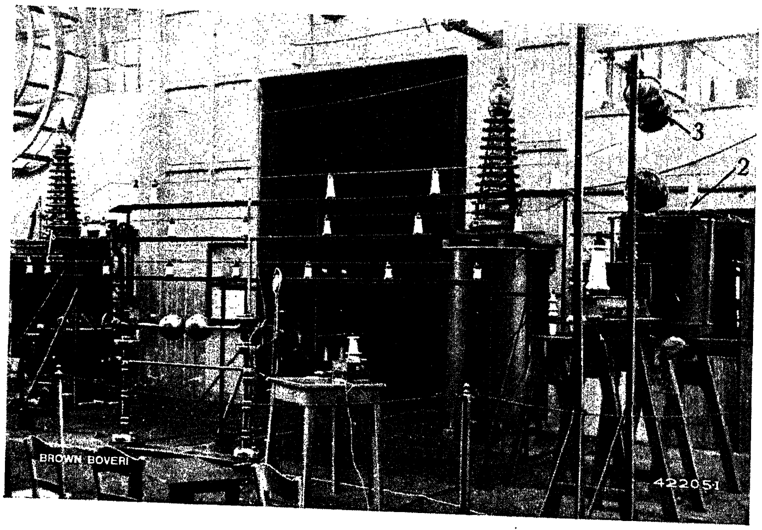


Fig. 6. — Model network.
1. Conductors in the plant, with supporting insulators.
2. Transformer with bushing insulators.
3. Overhead line.

In order to study the dangerous effects of surges on electric installations a so-called *artificial lightning* or *impulse generator* (Fig. 5, item 1) for voltages up to 1,000,000 V was put into service as early as about eight years ago in the high-voltage testing department of Brown Boveri & Company, Ltd. A battery of condensers charged with D. C. and in parallel connection is discharged connected in series with the object to be tested to provide high impulse voltages similar to those caused by lightning.

Surges (lightning or impulse voltage test) were passed through a conductor

300 m long on to a model of a substation (Figs. 5 and 6), whereupon contrary to expectations, flash-overs occurred on the *bushing insulators*, despite the fact that previous tests at 50 cycles had shown a 20 % higher flash-over voltage than for the *supporting insulators*. In order to prevent flash-overs, the insulation of the substation could be strengthened, but this would not be economical. By installing a *coordinating spark-gap* at the entrance to the plant the flash-overs on the insulators could be avoided. A flash-over on the coordinating spark-gap means, however, that the service is interrupted, even if there is no material damage done. Only the installation of a *Resorbit lightning arrestor* is really effective. It protects the plant against flash-overs and service interruptions, requires no attendance and is always ready for service. Even in *plants where the insulation is very poor*, no flash-overs occur, a fact proved by the demonstrations, the model substation being insulated for three different voltages, namely 24, 11, and 3·7 kV.

d) *Mutator testing department.*— Since the introduction of *grid-control* for *mutators* these have succeeded in penetrating into an increasing number of fields which were hitherto closed to them. Most prominent of these is the important problem of the *distribution* and *regulation of power* which is accompanied by difficulties when large networks are interconnected. If a power station, the generators of which are operating in parallel on a common busbar, supplies in addition to the ordinary network also a large consumer with a constant quota, then the power regulation is simple. When a second large consumer with a fixed power consumption is added, then the required division of the supply for the individual feeders can only be obtained by dividing up the bus-bars, that is by means of separate services. An undivided service is possible, however, by inserting *A. C.-A. C. mutators* on the individual outgoing feeders with constant load. In this way the turbines and generators are used to much better advantage and the independent operation of the different power stations is thus assured. A trial installation for 200 kW was demonstrated whereby, for the purpose of exchanging power, two networks each 50 cycles, were coupled together *without any previous synchronizing*. By means of the grid control the power was regulated as desired and independently of the network frequencies.

Power transmission with the aid of *high-voltage direct-current*, the advantages of which when compared with three-phase transmission are generally known, has been thoroughly studied. Since the generation and distribution of power are most economical when using alternating current, the *high-voltage mutator* is particularly suitable for the double conversion which is necessary. To further its development a test plant was built comprising two mutators for 60 kV, 2000 kW each being capable of alternately operating as a power distributor or power consumer. One of these mutators was demonstrated with resistance loading, at a voltage of 50 kV and 30 A; it was shown that the direct-current voltage could be continuously regulated down to zero by means of grid control.

The rapid operation of the grid control was demonstrated by extinguishing *short circuits* by means of the grids so rapidly that a thin wire in the path of the short circuit did not even glow, whilst with ordinary interruption by a circuit-breaker it "blew" with a really explosion-like effect.

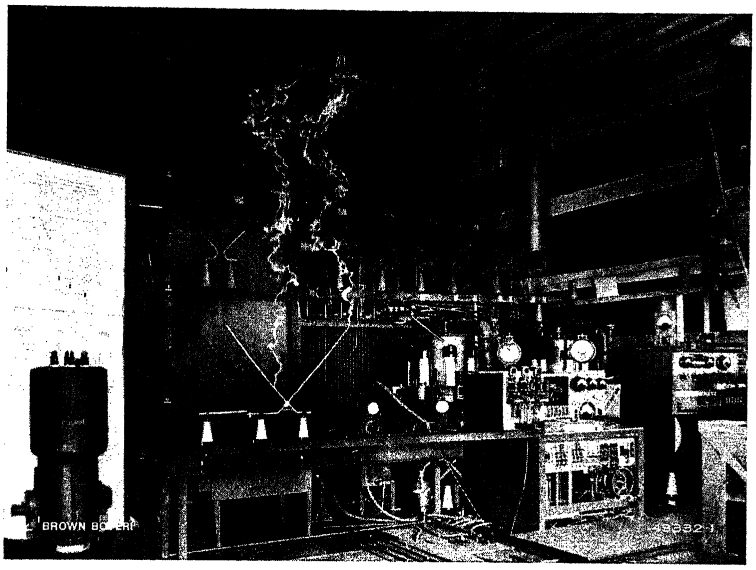


Fig. 7. — Mutator test bed.
Small mutator on left.
On right, direct-current high-voltage transmission; arc at 50 kV and 30 A.

The *high-voltage D.C. arc tests* were impressive, the working current being led over horn gaps in such a way that an arc several metres long, as shown in Fig. 7, was produced. This photograph is particularly noteworthy, because the arc is just about to be extinguished, this being recognizable by the fact that underneath, between the horns, a fresh ignition is already commencing.

For *smaller powers* the *small air-cooled mutator* (Fig. 7, left) should find application in fields where hitherto only glass-bulb mutators were representated, this being due to the robust and indestructible construction, lower losses and unlimited life of the former.

Fig. 8. — Exhibition of small articles.

1. Small single-phase motor.
2. Standard motor up to 45 kW.
3. Rotor with aluminium cage.
4. Three-phase shunt motor.
5. Protective device against accidental contact.

e) *Machine testing shop.*— Whilst the demonstrations in the other works departments were primarily concerned with manufactures which with the exception of relays, regulators and various apparatus, are not mass-production articles, the exhibition in the machine testing shop (Figs. 8 and 9) was devoted entirely to machines and apparatus made by *series production.* Particularly articles produced in series, if they are to be of a high quality and remain so, necessitate constant new development work.

One of the newest productions is the small *single-phase motor* (Fig. 8, item 1). It starts as a commutator motor. When in operation the commutator is short-circuited and the brushes lifted; the motor then runs as a standard *induction motor.* Only this design *without* condenser allows rapid starting with about four times the starting torque and only two to two and a half times the starting current. Motors built for a power range of about 0·1 to 0·37 kW can be connected up to any 220-V lighting system protected by 6-A fuses. This motor which is *noiseless* and does *not interfere with wireless reception* is the ideal motor for *small power services;* in addition to the standard form, it is also supplied in a variety of special designs, so that suitable motors are available for all purposes such as for refrigerators, oil-firing systems, pumps, ventilators, washing machines, etc.

In addition to the small motors, various designs of standard *three-phase motors* (Fig. 8, item 2) up to 45 kW were shown, together with modified types such as loom motors, machine tool driving motors, etc., proving that even here a suitable motor can be supplied to meet every purpose and special case. Besides the robust construction of the housing, shaft and roller bearings, high quality design of windings and insulation, particular attention has been devoted to the *design* of the terminal box. Conduit and cable connections of various kinds *facilitate installation.* There are also well-designed constructions for *building switchboxes on to the motors.*

Squirrel-cage rotors (Fig. 8, item 3) for standard induction motors up to 3 kW were shown as a novelty, the *cage* being *cast in aluminium* according to a special method and resulting in an indestructable rotor capable of withstanding the heaviest vibrations occurring in service.

Although the standard drip-proof type of motor is the most reliable for most applications, the *totally enclosed motor with surface cooling* is the best for *heavy-duty, dirty, damp services where acid fumes and other vapours are present.* The careful attention paid to its ventilation, combined with exhaustive studies and tests, has made it possible to build an *externally-cooled enclosed motor which is only slightly bigger than the protected drip-proof type of motor.* In view of the severe service conditions for which these motors are intended, special attention has been devoted to the insulation of the winding in the slot and to the impregnation.

Keen interest was also displayed in a motor of *standard series production,* which at the time of the visit had been running under water for nearly half a year (Fig. 8 — foreground).

Two practical examples of *three-phase shunt motors* were shown. The *spinning regulator* fitted to one of these motors (Fig. 8, item 4) enables the motor speed to be *automatically* adjusted to suit

Fig. 9. — Exhibition of small articles.

1. Switchbox with various forms of connection.
2. Small switchbox.
3. Remote-controlled switch, small contactor.
4. Welding set.
5. Welding transformers.
6. Regulating device for multi-point welding plants.

the spinning method and this, combined with a driving motor the speed of which can be regulated smoothly and without loss, guarantees *increased production and a uniform yarn quality*. The other motor, the brushes of which are operated by an auxiliary motor built-on to the main motor, can be started, regulated and stopped by push-button and contactor control. The speed of shunt motors is not seriously dependent upon the *load* or *fluctuations in the voltage*. It can, as already mentioned, be regulated simply by *brush displacement without auxiliary apparatus*. The range of regulation is normally 1 : 3, but can also be greater, for example 1 : 15. The excellent features of the Brown Boveri three-phase shunt motor make it suitable for *all variable drives* in all branches of industry.

Amongst the *switchboxes with thermal releases* (Fig. 9, item 1) which are built for rated currents up to 640 A, one of the most interesting series-production exhibits was the *small-motor protection switch* up to 25 A rated current, various designs being shown, namely a *hand-operated switch* (Fig. 9, item 2) *with* and *without* low-voltage tripping device and also a *magnetically operated remote-controlled, oil-immersed switch* (Fig. 9, item 3); the multifarious ways of connecting up the switch being also shown (Fig. 9, item 1).

Another innovation is the *protection device against accidental contact* consisting of a fault-voltage coil which can be built into all switchboxes and trips the switch as soon as, for example, a voltage exceeding 25 V occurs on the housing of the motor in question, due to an insulation fault. The method of operating this device which offers additional protection against accidents, was demonstrated (Fig. 8, item 5).

A *star-delta switch* was used to demonstrate how a carefully designed construction can ensure the proper operation of the switch. A change-over from star to delta can only be accomplished quickly; if switching-over is done slowly, with consequent risk of undesirable peak currents occurring, the movement becomes locked and the switch opened.

All these switchboxes are provided with *thermal releases* which are supplied with the motor current and thus directly heated. By this means, contrary to indirectly heated or transformer-fed tripping devices, the heating characteristic of the release can be completely adjusted to suit the line or motor to be protected and thus a really perfect protection is obtained. The direct-heated thermal release is *short-circuit proof* and interrupts large short-circuit currents, as demonstrated, with such lightning-like rapidity that the ammeter pointer receives an impulse which is only just visible. It is clear that a switch provided with such a release does not require *any* additional quick-releasing device.

The following were also on view:— *contactors* in various designs for motor control purposes, *drum-type switches* for control purposes, *control switches, push-button switches, pilot lamps,* in short, apparatus which can be used for controlling plants of all descriptions, for mounting *inside* and *outside* switchgear installations.

Amongst series production articles are also included *welding sets* (Fig. 9, item 4) for direct-current arc welding and *welding transformers* for alternating-current arc welding (Fig. 9, item 5). The direct-current welding sets built now are distinguished by their dynamic characteristic, that is by their lack of inertia and also the simplicity of the regulation of the welding current even with *remote regulation*, their high efficiency and indestructible construction. Standard monobloc designs are provided for currents from 10 to 180 A, 30 to 300 A and 50 to 440 A. The Brown Boveri welding set is equally suitable for *thin sheet welding* or heavy horizontal, vertical or overhead welding.

The new welding transformer (Fig. 9, item 5) with *smooth regulation* supplied in two sizes for 12 to 135 A and 18 to 250 A, is characterized by favourable welding features and enjoys a very great vogue.

For many years now Brown Boveri have been building reliable direct-current multi-point welding plants for use in large works such as shipyards, coach-building works, boiler shops, etc., where a large number of welding points are required. Due to the inductive welding-current regulator these operate with a constant network voltage of 40 V. This extremely low working voltage eliminates all danger for the operating staff. The latest achievements in this field are the *inductive stepless welding-current regulators* (Fig. 9, item 6). The fortunate combination of inductive and ohmic resistance in the present form results in these plants being very economical and possessing very favourable welding features which are particularly valued for example in shipyards where two-thirds of all welding work must be done vertically or overhead.

(f) *Steam turbine testing department.*— The former design of electric boilers is liable to be affected by short circuits when the working voltage exceeds 10 kV and the electrodes and porcelain parts wear out too rapidly. To meet the demand for high voltages the *high-voltage water-jet electric boiler* was developed some years ago. This boiler has found a large market due to its low operating costs, reliability and rapid regulation. During the last year 12 boilers with a total output of over 30,000 kW for working voltages of from 6 to 16 kV were put into service and they all operate very satisfactorily in every respect.

The latest development in this field is the *low-voltage electric boiler* which operates with immersed electrodes. In addition to its compact design it has an extensive regulating range combined with a low initial cost and is very economical in service. It is built both as a *steam* and a *hot-water generator*.

Demonstration tests with a low-voltage electric boiler of this type for 500 V, 500 kW showed in a most convincing manner the simplicity of this new design.

A tour through the workshops proved very attractive, due to the many interesting machines and apparatus which were to be seen in the course of construction. Many visitors were obviously impressed by the comparatively large activity in the workshops despite the difficult times. It must, however, be generally realized that here, as everywhere, a fair amount of employment does not always signify that prices are correspondingly good, especially nowadays. It proves, however, the intention of the firm to keep the essential part of its employees and workmen as fully occupied as possible despite the crisis.

Brown, Boveri & Company, Ltd., hope that by means of this visit on November 20th, 1935, their friends and other interested parties have become better acquainted with their latest designs, and that the confidence existing between manufacturer and consumer has thus been strengthened.

(MS 975) *K. Kupper. (Opp.)*

LIGHTNING ARRESTORS FOR HIGH AND MEDIUM-VOLTAGE SYSTEMS.

Decimal index 621.316.933.3.

INTRODUCTION.

THE latest investigations into electric storms have contributed valuable data to existing knowledge on the subject of the dangers to which electrical plants are exposed from atmospheric electricity as well as on the nature, intensity and frequency of occurrence of voltage surges due to storms. Certain principles were thus established with certainty and allowed of designing lightning arrestors possessing appropriate characteristics. On the other hand, the latest laboratory researches on the subject of the behaviour of waves — notably the impulse generator and the cathode-ray oscillograph — allow of testing protective apparatus to determine their efficacity, in the test room, itself. The Resorbit lightning arrestor, for example, was developed after the most thorough studies had been carried out, after innumerable tests and also after practical service data had been collected. In the following article high-voltage protective arrestors will be, first, described and then lightning arrestors for medium voltages.

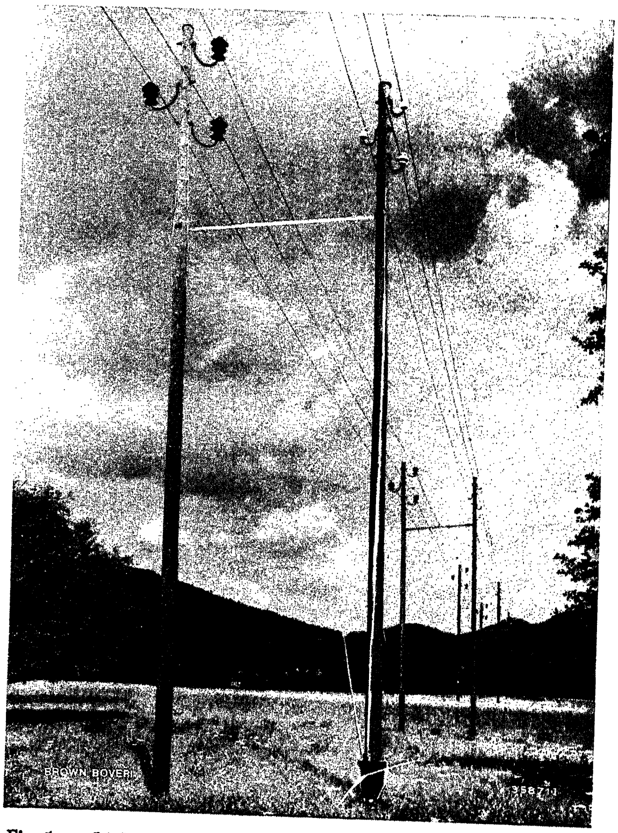


Fig. 1. — Lightning stroke on a 50-kV line (left) carried on wooden poles.
The discharge was carried over structural iron parts to the poles of the 8-kV parallel line (right) and led from here to earth. 13 successive poles showed similar traces of defects.

I. DUTY OF LIGHTNING ARRESTORS FOR HIGH VOLTAGES.

Generally speaking, the object of connecting lightning arrestors to a plant is to protect it against the over-voltages which might endanger the insulation. Practice has shown, however, that it is also advisable to use automatic quick-acting regulators, or other similar apparatus operating automatically, to keep down voltage rises caused by load ruptures or by generators over-speeding. Further, it has been proved that the consequences of intermittent earthing are best eliminated by using extinguishing coils, which are being used in ever increasing numbers on high-voltage systems. As regards over-voltages created by cutting out lines or transformers operating under no load or else by rupturing short circuits at the end of long lines without bifurcations, it can be said that the electric stresses set up are really in no way dangerous for high-voltage material if it be insulated according to the best modern practice.

Trouble in high-voltage plants is, generally, due to direct lightning strokes. Numerous statistics from various plants show, however, that in systems up to about 37 kV rated voltage, trouble due to indirect lightning strokes is more frequent. Thus, for example, there were thirty cases of circuit tripping on an 8-kV system due to indirect strokes while there were only two circuit-breaker operations, which were due to direct hits, on a 50-kV parallel line running close to it. Fig. 1 shows the mast which suffered most and which split down its whole length owing to a lightning discharge.

It is remarkable that on both sides of the pole in question there are 6 others — making a total of 13 poles — which show fainter signs of the stroke; no insulator fault could be detected. On the other hand, flash-overs on the 50-kV transformer terminals occurred in a substation 1·5 km away, which, however, did no damage to the windings. This trouble is characteristic as regards the determination of the dangers caused by storm over-voltages to which high-voltage systems of different voltage ratings are exposed.

Over-voltages due to electric storms generally take the form of a transitory wave of very short duration (a few micro-seconds) but, often, of dangerous amplitude. The steepness of the front of such waves is, very rarely, the cause of winding damage when the windings are well insulated; on the other hand, there are numerous flash-overs on insulators caused by the high amplitude of the wave. The first duty of lightning arrestors is, to protect plants against trouble of this nature by reducing the over-voltages due to electric storms so that they do not attain a value dangerous to insulators. The properties of the apparatus must be such that they can carry out this duty.

II. CONDITIONS TO BE FULFILLED BY THE LIGHTNING ARRESTOR.

A lightning arrestor can only protect a plant against flash-overs when its own ignition voltage is lower than the flash-over voltage of the insulators of the plant, this particularly in the case of impulse stressing. In order to limit the action of the lightning arrestor to the protection of the plant against atmospheric over-voltages and, at the same time, to prevent too frequent acting as a result of over-voltages due to earth faults or to circuit interruption, its ignition voltage must be higher than about 2·6 U to 3 U, for example (U being the rated line voltage). The arrestor will then only discharge under the influence of such over-voltages as are a real danger to the plant despite their short duration. According to this principle, lightning arrestors up to 37 kV rated voltage should have an ignition voltage which is lower than the flash-over voltage of the insulators for the rated voltage in question. Further, it is possible by proper arrangement of the sparking gap of the arrestor, to keep the *time lag of the discharge* below 0·2 micro-seconds which means a considerably greater protection against impulse stressing. In other words, the *impulse factor*[1] and, therewith, the ignition voltage of the arrestor are made considerably smaller than those of the insulators being protected.

In order to attain a sufficient reduction of the over-voltages it is necessary to lead off a considerable portion of the wave current to earth, through the arrestor, this during the whole duration of the dangerous wave amplitude.

It is an easy matter to estimate this current, in function of the amplitude of the wave μ and of the *residual voltage* μ_R remaining on the arrestor and thus to arrive at an estimation of the *conductive capacity* which is required. The arrestor current at the end of an open line attains the value

$$I_R = \frac{2\,\mu - \mu_R}{Z} \quad (Z = \text{wave resistance of line}).$$

If the arrestor is connected in series with the line, the current is given by the formula

$$I_R = \frac{2\,\mu - 2\,\mu_R}{Z}$$

Thus, the arrestor must, practically, carry a current double the value of the wave current, when the residual voltage μ_R — that is to say the voltage drop in the arrestor resistance — remains relatively low. This residual voltage which may last for several micro-seconds must never attain or exceed the flash-over voltage of the insulators. The fulfilment of this latter condition is fundamental for efficient protection.

Further, the arc ignited in the arrestor by the over-voltage must be extinguished with absolute certainty, whatever the strength of the discharge current of the wave and the angular displacement of the voltage on the system. This condition must be absolutely fulfilled when the system is working with a 10 to 20 % increased voltage and, at the same time, has developed an earth fault. A good arrestor must, therefore, be characterized by an excellent *extinction capacity*. It is very important that the current still flowing under

[1] By impulse factor is meant the ratio of ignition voltage under impulse stressing to the peak value of the ignition voltage under normal rated frequency.

line voltage be reduced to a minimum and that the arc be extinguished, at the latest, at the first passage of the current wave through 0.

Finally, it is obvious that a very high degree of *service reliability* must be demanded of a protective apparatus as it must never be allowed to degenerate into an additional source of trouble to the system. Thus, in designing the lightning arrestor, its insensibility to weather (damp, frost, etc.) and its imperviousness to other influences when in service must be seriously considered as well as its purely electrical properties.

It is not an easy matter to attain, simultaneously, a high extinction capacity such that the arc will be suppressed with certainty at the first passage of the current through zero, in conjunction with a capacity to carry off a heavy discharge, using a low ohmic value of the series resistance to give a low residual voltage. At the moment of extinction of the arc, the series resistance must again present a high ohmic value in order to throttle efficiently the tendency of the line current to follow the path taken by the discharge and to extinguish it completely in the multi-spark-gap device.

The desired result is best attained by using resistances which change with the applied voltage. These resistances are connected in series with an ignition gap and an arc-extinguishing gap. The conductivity of such resistances increases practically immediately as soon as a high voltage is applied across them and decreases as the voltage drops. In this way, it is possible to reduce the service current tending to follow the path of the discharge to a sufficiently low value, despite the high conductive quality of the arrestor, and also to assure its interruption. A resistance dependent on the voltage applied to it and in series with multi spark gaps is, therefore, the basis of the new arrestors. These two essential constructive elements are considered in more detail in the following paragraphs.

III. INFLUENCE OF THE DESIGN OF THE ARRESTOR ON ITS IGNITION VOLTAGE AND IGNITION TIME LAG.

Much theoretical and experimental work has been done to discover the best design of gap for arrestors. Technical literature and patent papers on this subject are numerous and contain a variety of suggestions to solve the problem. The amount of literature available is a proof of the difficulty of the question.

The ignition time lag of the arrestor is determined by the following factors:—

(a) the time lag in the discharge of the ignition sparking gap;

(b) the time lag in the ignition of the *multi extinguishing gap;*

(c) the time lag requisite for the resistance in series to change from a high to a low ohmic resistance.

It must be stressed here that by inserting an ignition sparking gap a, the important elements of the arrestor are entirely shielded from dielectric stressing under normal service conditions. The ignition sparking gap is always subjected to the phase voltage and can also be under the line voltage if the system has a permanent earth fault. The multi extinguishing gap b, the electrodes of which are made of metal, serves to extinguish the arc and break the service current tending to follow in its track; it is an essential part of an arrestor having a resistance which varies with the voltage.

The tests carried out have shown that the ignition sparking gap, designed with spherical electrodes and the multi extinguishing gap, designed with electrodes of suitable shape suffice to fulfil the severest conditions which an arrestor can be called on to meet. The ignition voltage of the arrestor remains, practically the same, whether there is an ignition sparking gap or not and its ignition time lag is less than 0·15 μs.

TABLE I.

Spherical spark gap spheres of 10 mm diameter						One element of the multi-sparking gap		
1. Static ignition voltage (measured with DC)								
2 × 1240 V 1180 V 1220 V, average 1200 V 1170 V 3 × 1180 V						1400 V 2 × 1420 V average 1412 V 2 × 1410 V		
2. Ignition voltage under impulse stressing								
Exposed to mercury vapour quarz lamp rays			Not exposed to mercury vapour quarz lamp rays			Not exposed to mercury vapour quarz lamp rays		
Volts	Time lag in ignition μs	Impulse factor β	Volts	Time lag in ignition μs	Impulse factor β	Volts	Time lag in ignition μs	Impulse factor β
2810	0·65	2·35	2070	0·29	1·73	1440	0	1·016
2880	0·71	2·39	2230	0·33	1·86	1440	0	1·016
2500	0·50	2·08	1580	0·10	1·32	1470	0·04	1·040
2080	0·28	1·73	1740	0·16	1·45	1460	0·03	1·033
2700	0·63	2·24	1880	0·24	1·57	1510	0·06	1·066
2330	0·45	1·94	2100	0·35	1·75			
2550 [1]	0·54 [1]	2·12 [1]	1920 [1]	0·24 [1]	1·60 [1]	1460 [1]	0·026 [1]	1·034

[1] Average figure

It is known that, under stressing by steep-front waves, the impulse factor is considerable when the distance between sparking electrodes is small. In order to attain a satisfactory extinguishing capacity, however, the multi extinction gap has to be made up of a great number of partial sparking gaps. Now, the ignition voltage of a gap of this kind increases, approximately, in proportion to the number of the elements of which it is composed, so that the latter have to be adjusted to 0·1 to 0·2 mm only, to prevent the ignition voltage of the arrestor growing too high. It is, therefore, essential to design the electrodes in some form which is an improvement on the spherical shape, as regards the ignition time lag as well as the impulse factor for small gap values. Although the accomplishment of this task seemed impossible, at first, it was, nevertheless, found possible, after exhaustive tests had been made, to develop a multi spark gap which satisfied all the conditions imposed. In order to be able to appreciate the qualities of the electrode design chosen, Table I is given containing some measurement results from comparative tests. The ignition voltage under surge stressing was measured on a spark gap between spherical electrodes and also between two electrodes on the multi gap system, the first having, under static stressing, a discharge voltage of 1200 V and the second of 1412 V. The difference is due to a disparity amounting to about 0·01 mm between the two sparking gaps.

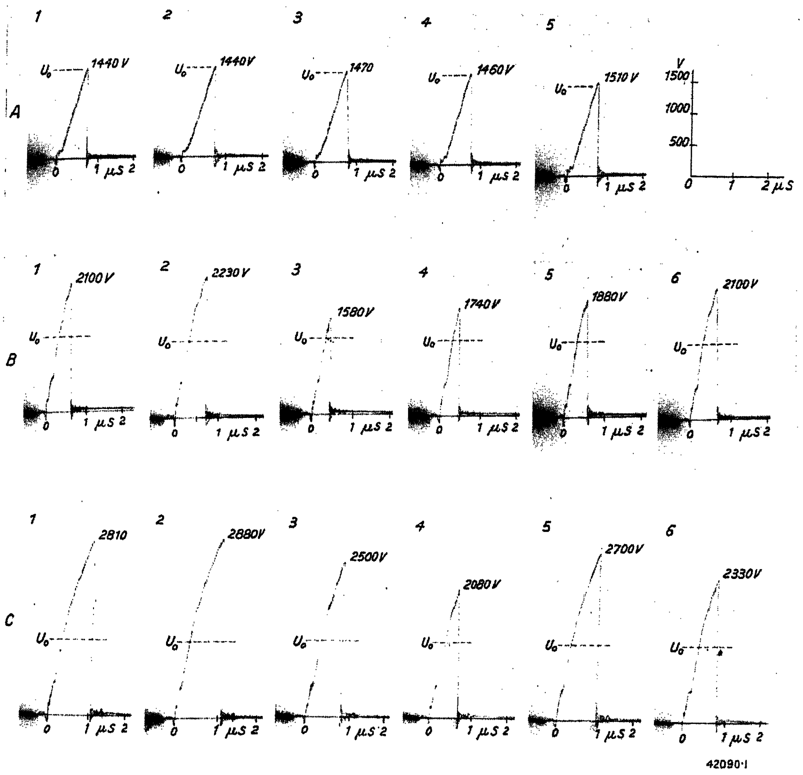


Fig. 2. — Cathode-ray oscillogram of ignition process on three different spark gaps.

A. One element of the extinguishing gap.
B. Gap between spheres of 10 mm diam. under rays.
C. Gap between spheres of 10 mm diam. not under rays.

The steepness of the wave front varies, somewhat, from one test to another, as can be seen from the cathode-ray oscillogram of Fig. 2 which shows all the measurements reproduced in the table. The average values in the last horizontal row show what a difference there is between the impulse factor of the spark gap between spheres (2·12) and the impulse factor of one of the elements of the multi spark gap. (1·034). Even by exposing the gap to the rays of a quarz lamp, which was placed close to it, to exert a powerful ionizing effect, the impulse factor of the gap between spheres could not be reduced below 1·6. The deviations of the various measurements from the average value are: —

for spark gap between spheres not exposed to rays from a quarz lamp

$+13$ and $-10\,\%$;

same exposed to rays from a quarz lamp

$+16$ and $-17\,\%$;

for an element of the multi spark gap

$+1{\cdot}5$ and $-2\,\%$.

The latter is, therefore, characterized by exceptional constancy of its characteristic.

The following measurements carried out by Dr. K. Berger in the very finely equipped laboratory of the Swiss Electrotechnical Society show that the complete Resorbit arrestor designed for 3·7/4·4 kV rated voltage possesses the same characteristic properties:—

ignition voltage at 50 cycles

12·3 kV (R. M. S.);

ignition voltage under surge stressing 22 kV:

$$17{\cdot}6\ \mathrm{kV_{peak}} = \sqrt{3}\cdot 12{\cdot}5\ \mathrm{kV\ (R.M.S.)};$$

ignition voltage under surge stressing 36 kV:

$$17{\cdot}6\ \mathrm{kV_{peak}} = \sqrt{2}\cdot 12{\cdot}5\ \mathrm{kV\ (R.M.S.)};$$

ignition voltage under surge stressing 178 kV

$$17{\cdot}6\ \mathrm{kV_{peak}} = \sqrt{2}\cdot 12{\cdot}5\ \mathrm{kV\ (R.M.S.)}.$$

The time lag in discharging is practically zero in all three cases and the impulse factor exactly 1. In the impulse tests with 178 kV (1 × 30) µs a spark gap between spheres connected in parallel to the arrestor only showed 3·5 kV (R. M. S.); after it had been exposed to the rays from a radium salt no more than 6 kV (R. M. S.) could be measured. These tests are a confirmation of the measurement results just tabulated. It is thus possible to get a quicker discharge from a relatively complicated spark gap made up of a number of elemental parts than it is from a gap between spheres under the ionizing effect of radium, this of course on condition that the elements of the arrestor be properly designed.

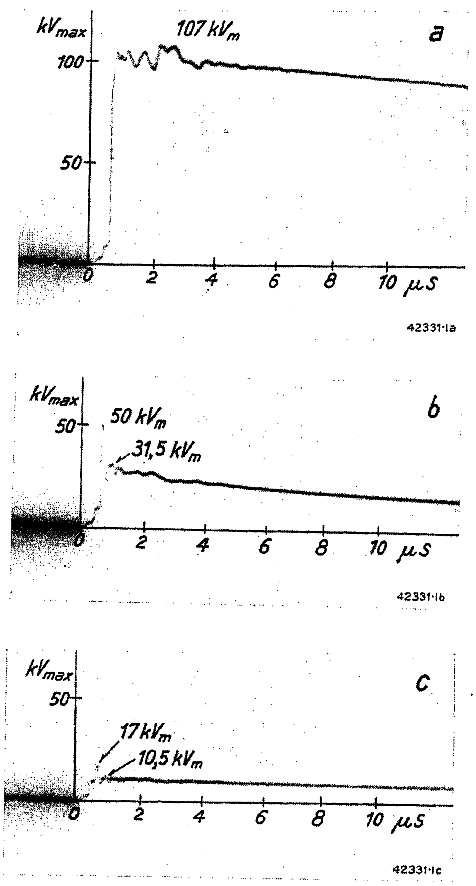


Fig. 3. — Influence on the impulse wave of two different arrestors.

a. Wave reflected at line end.
b. Remaining residual voltage when one of the well-known types of arrestor is used.
c. Residual voltage when Brown Boveri Resorbit arrestor is used and for the same rated voltage as in Fig. 3b.

A Resorbit arrestor for 15/18 kV tested by Dr. K. Berger by means of impulse waves, with a 360 kV (1 × 30) µs wave showed that the impulse factor of the arrestor does not exceed 1·35 and that its ignition time lag remains lower than 0·1 µs. These are two very advantageous results when compared with the results of measurements carried out on other types of arrestors and this is shown up by the following comparison. An arrestor for 16/20 kV rated voltage of the latest type — one which has been used extensively in practice in recent years — showed an impulse factor of 1·95 and an ignition time lag of up to 0·4 µs when it was tested under similar conditions and by means of the same surge generator. This comparison is clearer if the cathode-ray oscillogram of Fig. 3 is studied. a is a surge reflected at the end of a test line without an arrestor. b is the surge voltage at the same spot after an arrestor for 4/5 kV rated voltage of the same design as that just mentioned for 16/20 kV had been connected up. Finally, c is the impulse voltage measured under exactly the same conditions but after a Resorbit arrestor for 3·7/4·4 kV rated voltage had been put in. The comparison shows that the Resorbit arrestor has an ignition voltage and a residual voltage three times lower than the other apparatus although both have practically the same ignition voltage at 50 cycles.

In the following paragraphs, comparative values of flash-over voltages on insulators of corresponding rated voltage and the factor of safety, i. e. the protective value of a Resorbit arrestor will be given. This data demonstrates the advantageous protective qualities of this apparatus.

IV. PROPERTIES OF THE LIMITING RESISTANCE. RESORBIT RESISTANCES.

The properties of the limiting resistance also influence the ignition time lag of an arrestor, because the transformation from a state of high resistance to one of low resistance takes a certain time. According to the current-voltage characteristic of a resistance which varies with the voltage the lapse of time may differ. The resistances used recently for arrestors can be divided into two groups:—

(a) Resistances the characteristic of which in function of the voltage varies according to the equation $R = \frac{R_o}{U^\alpha}$, with $\alpha \geq 1$ and which are designated as *resistances dependant on voltage.*

(b) Resistances which only allow a measurable current to flow through them when the voltage across them has attained a given value U_o; for voltages higher than $U_s \geq U_o$ the voltage drop is constant, $RI = U_s =$ constant. Expressed differently:— the

voltage is independent of the value of the current flowing through them. In the following paragraphs these resistances will be termed *resistances with constant voltage drop.*

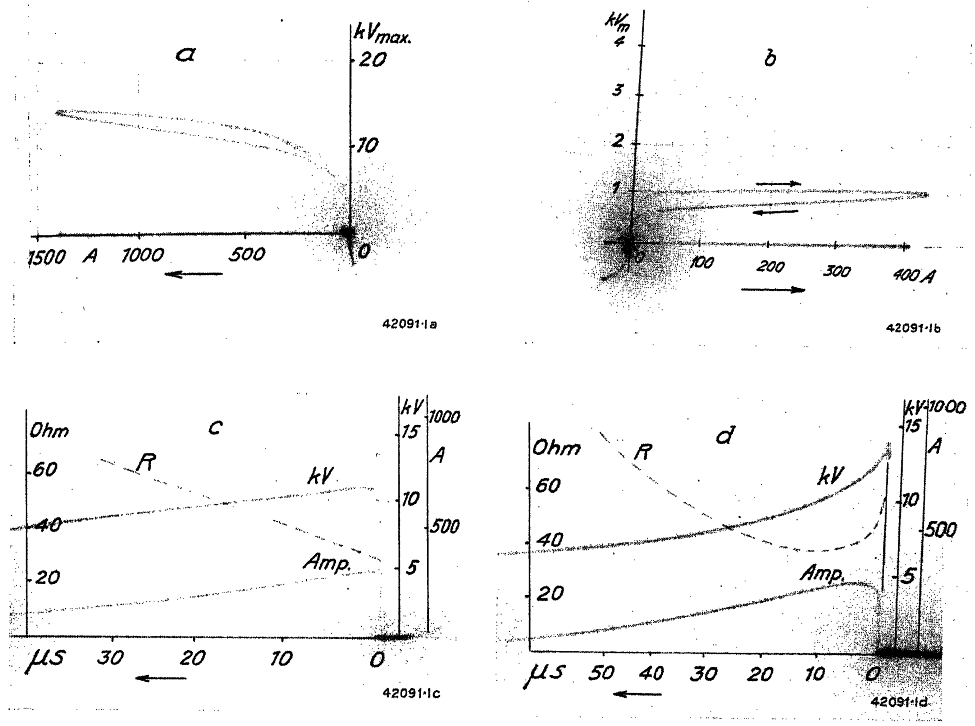


Fig. 4. — Characteristics of limiting resistances for arrestors.

(a) Current-voltage characteristic of resistance which varies with the voltage.

(b) Current-voltage characteristic of resistance with constant voltage drop.

(c) Current, voltage (kV) and resistance (R) of the resistance varying with the voltage in function of the time; impulse wave (1×30) μs.

(d) Current, voltage (kV) and resistance (R) of the resistance with constant voltage drop; impulse wave (1×30) μs.

Figs. 4a and 4b reproduce current-voltage characteristics recorded with the cathode-ray oscillograph. The recording of oscillograms of this kind can, however, be carried out with impulse waves having different steepness of front, so that the internal transformation process from high to low ohmic resistance can follow, with varying degrees of facility, the variations in voltage applied. If, now, it is desired to determine the time required for the transformation in question, it is necessary to determine the current flowing through the resistance, as well as the terminal voltage in function of time when using a predetermined wave shape. Figs. 4c and d show the oscillogram recorded with a (1×30) μs wave which brings out clearly the difference between the two kinds of resistance. The resistance with constant voltage drop takes much longer to transform than the one the resistance of which is dependent on the voltage. The voltage drop determines the residual voltage on the arrestor terminals during the discharge of an over-voltage and it must, therefore, be as low as possible, especially at the moment of highest amplitude of the wave, namely just at the beginning of the discharge. In order to attain the lowest ohmic value as early as the moment of discharge of the crest value of the wave it is, therefore, important to use limiting resistances which transform with a time lag as close to zero as possible. Generally, in low-voltage arrestors, the measure of safety, that is the difference between the flash-over voltage of the plant and the ignition voltage of the arrestor is much greater so that this quality of the limiting resistances is of much less importance. In any case, the Resorbit arrestors show either of the two characteristics according to the way they are made up and used. The high-voltage Resorbit arrestors, however, are equipped with resistances the characteristics of which are illustrated by the two oscillograms shown in Figs. 4a and 4c.

It has already been said that a good arrestor besides showing a low residual voltage, which must not exceed $2 \cdot 5$ U, must also have a high conductive capacity. It is only when the greater portion of the wave current has been led to earth through the arrestor that the wave voltage can be sufficiently reduced. The behaviour of the arrestor must, also, be faultless when relatively long waves have to be dealt with. For these reasons, the resistances should not be designed with regard to the momentary peak value of the current alone but to deal with a given electrical discharge expressed by $Q = \int i \, dt$, in ampere-seconds or Coulombs.

It should further be said that the temperature rise of the limiting resistance depends on its calorific

capacity and also on the amount of heat $P = \int i \, \mu_R \, dt$ developed. From this point of view, as well, it is advisable to keep the residual voltage R as low as possible.

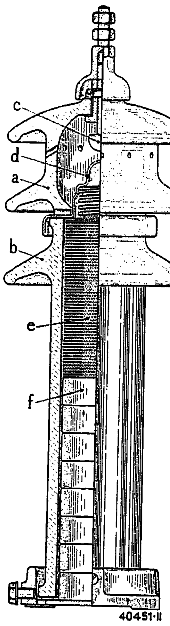


Fig. 5. — Section through a Resorbit arrestor.
a, b. Porcelain insulator.
c, d. Spherical shaped electrodes of ignition gap.
e. Extinguishing gap.
f. Resorbit discs.

These considerations show that the conductive capacity of an arrestor must be determined by the crest value of the current wave in amperes and the duration of the wave front in μs or, still better, by the crest value of the wave and its shape. Here, attention should be drawn to the new regulations laid down by the Swiss Electrotechnical Society[1] which prescribe the testing conditions for arrestors and in which an impulse wave of 1 μs front duration and 30 μs wave-tail duration to half-crest value is assumed. As compared to this, the American Institute El. Eng. Standards No. 28[2] gives a wave of (10×10) μs for the same tests. If these two wave forms are compared with regard to the amount of electricity Q flowing, the following figures are reached for an amplitude value of the current wave of 1500 A:

For the wave (1×30) μs according to SEV rules:— $0 \cdot 065$ A s (= 100 %).
For the wave (10×10) μs according to AIEE stand No. 28:— $0 \cdot 029$ A s (= $44 \cdot 6$ %).

Thus, impulse tests carried out, for example, with 1500 A produce quite different stressing, according to the shape of the wave. As regards the amount of electricity involved a test with 1500 A with a (1×30) μs wave is equal to a test at 3370 A and a (10×10) μs wave. The wave shape assumed by Swiss rules (SEV) correspond, to the latest data on the stressing of plants by over-voltages due to storms and cover most cases met with in practice.

[1] See Bulletin SEV of April 1935.
[2] See, also, A. M. Opsahl:— Surge currents in Protection Duties, El. Eng., year 1935, page 200.

V. THE RESORBIT ARRESTOR.

The Resorbit arrestor is composed of the following parts (Fig. 5).

Under the porcelain mantle a, are lodged the two spherical-shaped electrodes c and d which form the *ignition gap*. These are set for an ignition voltage which is lower than the flash-over voltage of the insulators of the corresponding rating. When in service, this ignition gap is continually under the line voltage and is amply insulated by porcelain for this reason, in order that the quality of the insulation should not deteriorate with time. In order to avoid the big discharge time lag which is inherent to a hermetically-closed sparking gap, the porcelain mantle is amply provided with ventilating holes.

The *extinguishing spark gap* e is in the interior of the hermetically-closed insulator b. It is composed of a number of superimposed elements which cause the arc to be extinguished very rapidly. The insulator b also contains the *resistances made of Resorbit* f. The number of elements in the extinguishing gap is carefully adjusted to the current-voltage characteristic and to the number of resistances, in order that the arc will invariably be finally extinguished at the first passage through zero of the current wave and this even if the voltage on the arrestor attains $1 \cdot 2$ times the line voltage. In this way, the service current is absolutely prevented from flowing off, after the dis-

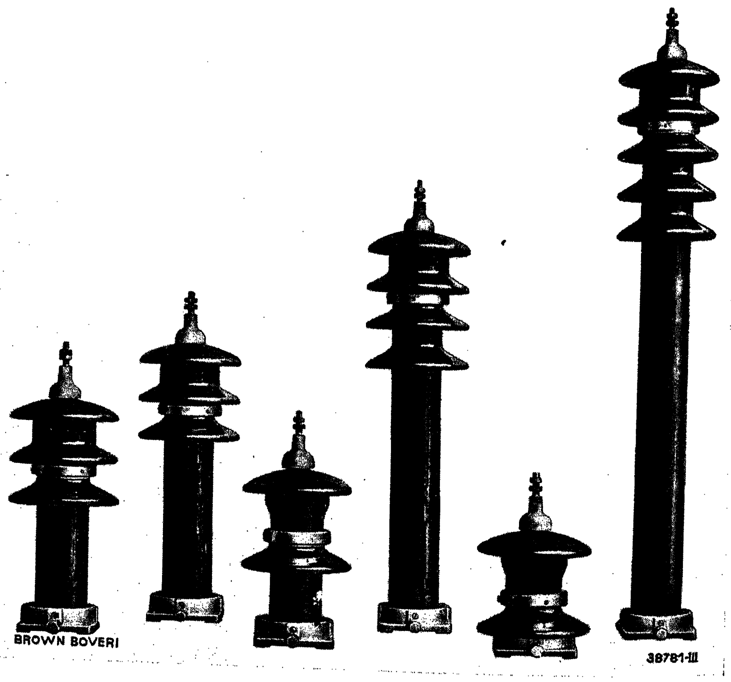
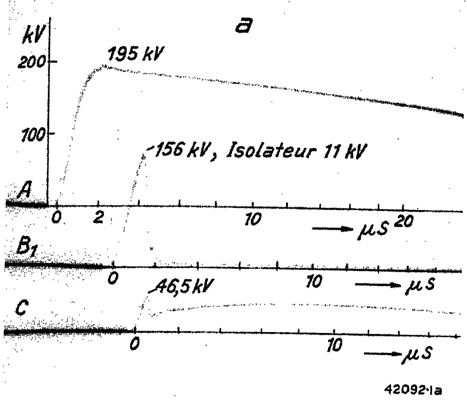
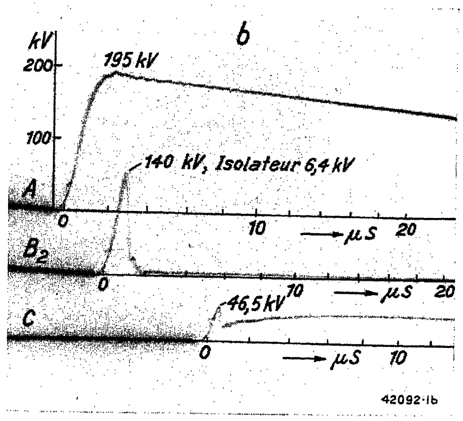


Fig. 6. — Resorbit arrestor for rated voltages of 3·7; 6·4; 15; 24, and 37 kV.

charge, and the apparatus is protected against over-heating or damage due to sparking. The shape given to the electrodes of the extinguishing gap was determined





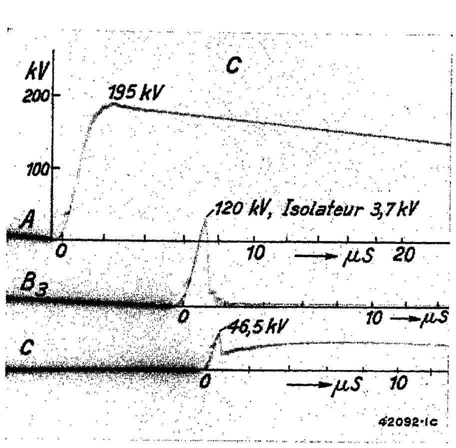


Fig. 7. — Protective influence of an 11-kV Resorbit arrestor.

(a) Protection of an 11-kV insulator.
(b) Protection of a 6·4-kV insulator.
(c) Protection of a 3·7-kV insulator.
A The impulse wave reflected at the end of the line.
B_1, B_2, B_3 Flash-overs on 11-kV, 6·4-kV, 3·7-kV supporting insulators.
C The impulse wave reduced by the arrestor.

after exhaustive study of the subject. In chapter IV it was said that Resorbit resistances were very dependent on the voltage and, also, that the residual voltage is low under heavy current loading. The increase in the ohmic resistance which takes place without any time lag and after the over-voltage has passed results in a limitation of the value of the service current flowing through the arrestor and facilitates the extinction of the arc by the action of the multi-sparking gap.

No parts of the arrestor are cemented, all parts being fastened together by weather-proof locking devices, so that such faults as are to be imputed to the absorption of damp by cement or resulting from low temperatures do not occur with these arrestors. As there are no moving parts or delicate organs in the make-up of the arrestor it can carry on service without any supervision whatsoever. Its design facilitates dismantling and supervision.

As already stated, high-voltage systems up to 37-kV service voltage are very sensitive to indirect lightning strokes and most trouble on these systems can be imputed thereto. On account of the experience gained in practice, the Resorbit arrestors have been developed for all rated voltages from 3·7 to 37 kV. These arrestors are of the single-pole type and are put up in groups of three near the stations to be protected (power stations or substations), either inside the plants or out of doors according to the space available. The space required is very small as the arrestors can be mounted in the same way as insulators either of the supporting or suspension type.

Fig. 7 gives some cathode-ray oscillogram records of measurements carried out, which show the efficiency and protective value of the Resorbit arrestor; these show in A a negative, 195-kV, impulse wave. This wave causes no flash-overs on the well-insulated test line. A supporting

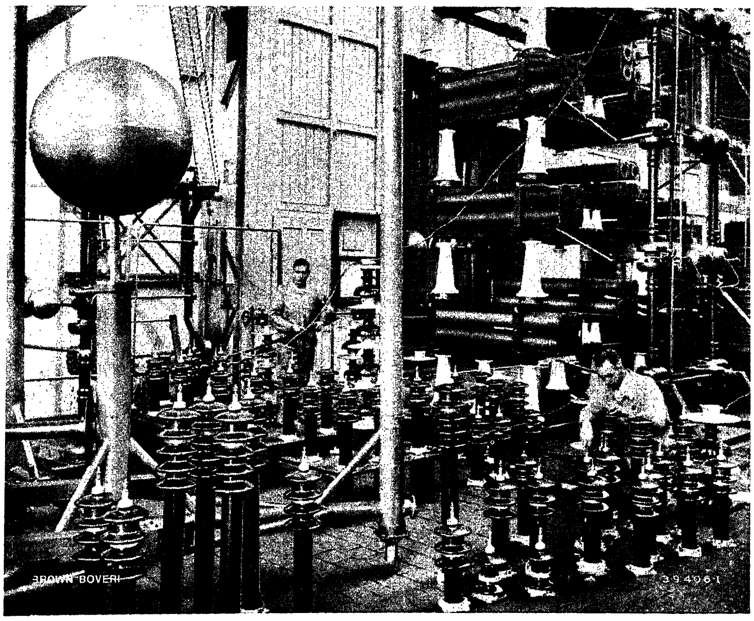


Fig. 8. — Impulse generator to test Resorbit arrestors.

insulator built for 11-kV rated voltage is now connected to the line and the same impulse test is repeated. As shown in oscillogram B_1, there is a flash-over on the supporting insulator at every impulse. By connecting up an 11-kV Resorbit arrestor these flash-overs cease, because the wave A has thus been transformed into a much smaller wave, according to the oscillogram C. The reduction of the impulse wave by an 11-kV arrestor goes so far that the flash-over on an 6·4-kV (oscil. B_2) supporting insulator and even on a 3·7-kV supporting insulator can be prevented with a great factor of safety, thanks to the arrestor igniting instantaneously and to the low residual voltage of the arrestor. In all three cases, the degree of security is, practically, the same with positive waves, because the flash-over voltage of the insulators is only 10 to 15 % smaller while the effectiveness of the arrestor does not depend on the polarity.

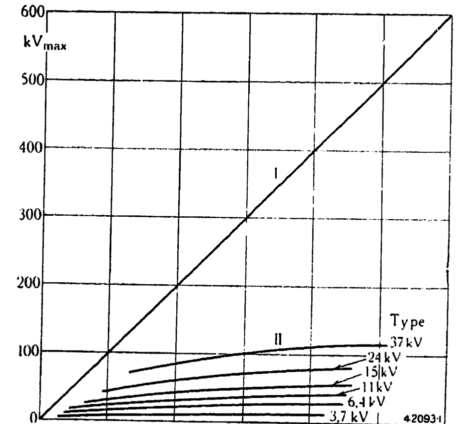


Fig. 9. — Characteristics of Resorbit arrestors of 3·7 to 37 kV.

Abcissæ:— Peak value of incoming surge wave.
Ordinates:— Voltage in head station.
I. Without arrestor. II. With Resorbit arrestor.

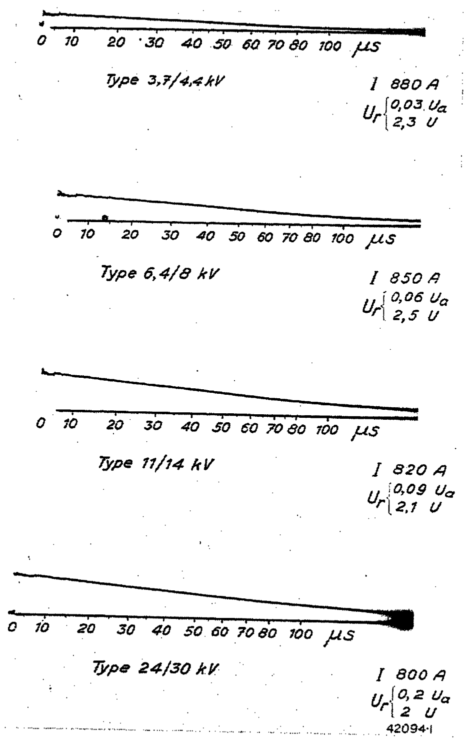


Fig. 10. — Cathode-ray oscillogram recorded during tests of arrestor types by means of the big impulse generator, in the laboratory of the Swiss Electrotechnical Society.

U. Highest allowable rated voltage of arrestor.
Ua. 440-kV crest value of reflected impulse wave at the end of the line.

Regularity in the operation of an arrestor can only be attained by careful balancing of the properties of the ignition spark gap and of the extinguishing gap. There are difficulties in the way of solving this problem and these difficulties have not always been solved in all the best known types of arrestor, although it has been done successfully in the Resorbit arrestor. The deviations from one arrestor to another of the same type, which cannot be avoided, must be reduced to a minimum by very homogeneous standard manufacture combined with careful testing. These tests must embrace both the measurement of the ignition voltage as well as the impulse characteristic (Fig. 8). The residual voltages measured on Resorbit arrestors under different impulse waves are shown in Fig. 9, as curves in function of the wave voltage. This illustration shows, clearly, the high protective value of the arrestors. It should be added that while the extinguishing capacity of the arrestor was being tested out in the high-power testing plant with an impulse test, the arrestor was simultaneously supplied with a voltage 1·3 times the line voltage.

After the determination of the new SEV regulations for over-voltage arrestors, some individual tests on different arrestor types were carried out by Dr. K. Berger in his laboratory, these tests being made, in some cases, under considerably higher impulse waves than are demanded by the above mentioned specifications. The arrestors were tested with the help of the big surge generator (C = 72,000 cm) with waves of (1 × 30) μs, the amplitude value of which attained 440 kV at the end of the line 900 m long. In order to test the extinguishing capacity of the arrestor, the test line was fed from the Olten-Goesgen power house, during the impulse test by a voltage of 1·2 times the line voltage supplied at the service frequency; this is in accordance with the regulations. In the majority of cases, extinction took place instantaneously and, if not, then always when the service current, which followed in the path of the discharge, passed through the zero value for the first time. During these individual type tests, 540 cathode-ray oscillograms were recorded and these demonstrate the per-

fect operation of the arrestor. Some oscillograms of the residual voltages on the terminals of the Resorbit arrestor are shown in Fig. 10. Despite the relative high value of the impulse current carried off the voltage wave was reduced to a few per cent of the crest value it would have attained without the arrestor and which would have amounted to 440 kV.

plants. Generally, too, old plants exist as well as new ones and the former are the seat of trouble even under less severe stressing. According to the regulations, low-voltage material has to be tested with, at least, 1500 to 2000 V (R. M. S.) during 1 minute. Its electric strength is generally considerably higher than this, especially when stressing of short duration

TABLE II.

Insulation tests on low-voltage material under impulse voltages.
Form of the impulse wave 1/500 μs.

Object tested	Break-down point	Conductor negative New	Conductor negative Old	Conductor positive New	Conductor positive Old
		E kV crest		E kV crest	
Plug switch	Contact spindle	5·6	4·1	3·5	
Thermal switch	Contact-cover		8·3		
Fitting with rotary switch	Thread ring-housing		3·7		
Fitting with pull switch	Connecting screw-housing	5·1			
Goliath fitting	Thread ring-housing	3·5			
Plug and coupling	Contact-housing		8·1		
Motor switch	Segment-spindle		11·4		
Small motor			5·6		
Multi-wire conductor cord GS 1·3/2·9 diam.	Wire-artificial sleeve	29·8	4·5—5·7	27·3	
Conductor cord for apparatus 2×1·3/8 diam.	„ „ „		57		
Wire with rubber sleeve insulation					
(a) White 1·1/3·7 diam.	„ „ „	17·4—56			
(b) Black 1·35/4·4 diam.	„ „ „	38—49	31	55·2	
Wire with rubber ribbon insulation					
(c) 1·1/3·1 and 1·15/4 diam.	„ „ „		2·9—3·9		
Bergmann tube 11 mm	Bare wire tubular sleeve	26·7	5·3		
Bergmann tube with wire b: sharp bend	Wire tubular sleeve	51·7	12·2		
with end cap	Wire-end cap	41·0	4·3		
Overload line insulators	Wire-supporting iron		72—79		47—49

VI. LIGHTNING ARRESTORS AND VOLTAGE LIMITERS FOR LOW-VOLTAGE SYSTEMS.

Service security in distribution networks operating at low voltages has been much increased lately, thanks to the progress made in the manufacture of insulating material. The quality mark introduced in some countries for apparatus and conductors and a tightening of the rules governing the building of low-voltage plants has done much to enhance security. Two dangers, however, which occur in many cases, are worthy of note:— the over-voltages due to storms and the accidental contact of the high voltage and the low-voltage systems. Thus, in Switzerland, over-voltages, at any point on a low-voltage system, of the order of 10 to 50 kV are relatively frequent — up to about 200 cases per year. These are, generally, due to the influence of a lightning discharge which lasts a short time. Higher over-voltages due to a direct lightning stroke are much rarer occurrences, but they generally cause serious damage. The quality of insulation of low-voltage systems is very variable and depends on whether the plant has overhead lines, cables, indoor installations, workshops or portable

is encountered. Some measurement values of flash-over or break-down voltages are given in Table II. These show that low-voltage material, as well, when submitted to impulse stressing can withstand relatively high voltages, without trouble developing. A domestic installation, however, ages fairly rapidly especially if the rooms are damp or some of the apparatus is of the portable type. Outdoor line insulators, on the contrary, maintain their dielectric strength for years, practically without a change. As the highest impulse flash-over voltages of these insulators reaches about 80 kV crest value, it must be reckoned that, as compared to indoor installations, the overhead transmission lines are always very amply insulated, so that the over-voltages are more likely to cause trouble to the former.

As a first protective measure, the neutral-point wire — if there happens to be one — can be earthed as frequently as is possible. This strengthens the damping down of transitory surges and, further, the earthed neutral acts as a protective lead when a direct stroke of lightning occurs and leads to earth most of the over-voltages. This measure does not prevent voltage waves on the phase conductors such as occur

as a result of indirect lightning strokes. In order to introduce reliable voltage limiting to systems with or without neutral conductor, it is advisable, with wooden poles, to earth the iron fixation parts of the insulators in the vicinity of the station because if this is not done the whole line insulation including the wooden lengths determines the limitation of the wave peak, the flash over voltage being about 400 kV crest value per metre of pole height. Despite all these measures, voltage waves up to about 80 kV crest value can develop freely along the lines without flash-overs on the insulators, and penetrate into house installations. These waves can be reduced by weakening the insulation at definite points and the penetration of the waves to the inside installation prevented. This object is fulfilled by arrestor type HFo.

Fig. 11. – Single-pole over-voltage arrestor Type HFo.

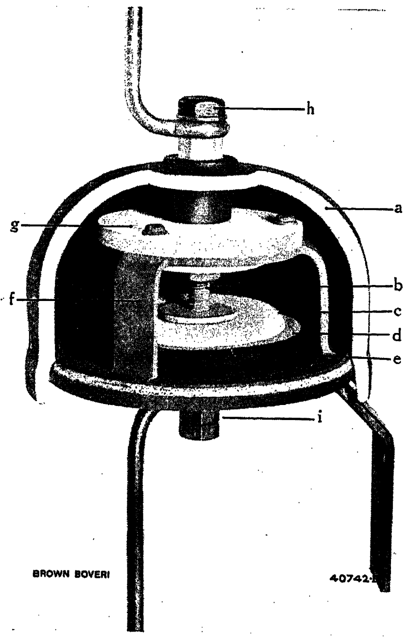


Fig. 12. – Interior design of the arrestor.

a. Protective hood.
b. Threaded bolts.
c. Electrode.
d. Counter electrode.
e. Resistance body.
f. Support.
g. Insulating plate.
h, i. Terminals.

The best defence against the second source of danger is also to put in arrestor Type HFo because it both acts as a voltage limiter and forms an earth connection in the case of the high and low voltage systems coming into contact; this protects the low-voltage side from a dangerous voltage rise. At the same time, care must be taken that the earth electrodes to connect up the arrestors have as low a contact resistance as possible, because, if this is not so, the voltage drop across these electrodes can suffice to endanger the plant. It is thus recommendable to make the earth connections with several copper strips arranged in star formation and buried, as this generally gives the lowest ohmic value. It should be said, also, that when the high-voltage system gets into contact with the low it is due to excessive stressing of the plant which has been going on for some time and which leads to short circuits at far lower values than those given in Table II. Further the low-voltage fuses are generally unable to rupture the short circuit, this because of the increased voltage and, thus, the danger of fire increases, especially if the fusing current of the high-voltage fuses is too high.

The over-voltage arrestor Type HFo (Fig. 11) is composed of a spark gap in series with a limiting resistance the properties of which are suitable to the special requirements which are demanded of a low-voltage arrestor. The particular form of the sparking gap which facilitates the extinction of the arc by magnetic blow-out and the suitable characteristic of the resistance (constant voltage drop) allow of combining a low ignition voltage with a high extinguishing capacity. Its internal arrangement (Fig. 12) is of the simplest:— a threaded bolt b is let into the protective hood a, made of material impervious to weather. This bolt carries at its lower end the upper electrode c of the ignition gap. The second electrode d is directly set in the resistance body e and ensures uniform current distribution in the said resistance. The frame f and insulating plate g holds the whole inner part together. The protective hood is pressed on tight to the lower plate and makes a weather-tight fitting. Connection of the arrestor to the system is by terminal h and the connection to the earth is through screw i, below. Thus, the arrestor has no moving contact parts or blow-out coils which experience has shown to be sources of mechanical or electrical trouble, as time goes on and which lead to the apparatus failing to act.

Further, the limiting resistance used in the arrestor HFo has the additional property of acting as an insulating body when the current goes back through zero, and it allows no current to pass when the service voltage appears again across the terminals. Together with the spark gap in series which blows out the discharge spark, this apparatus is able both to render dangerous over-voltages innocuous and to stop immediately the flow of line current following the path of the arrestor discharge.

The ignition of the arrestor can be said to be without any time lag and to take place as soon as

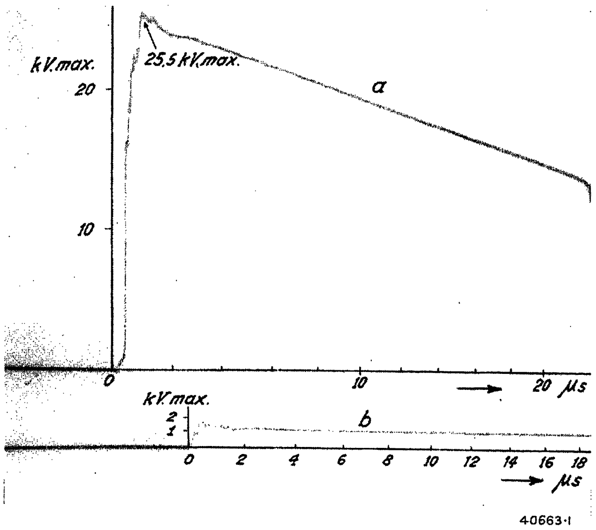


Fig. 13. — Cathode-ray oscillogram of the voltage drop through arrestor Type HFo.

a. Impulse voltage without arrestor.
b. Impulse voltage after arrestor has been connected.

its ignition voltage has been attained. The ignition time lag has been reduced to an extremely low value, by suitable design of the different elements of the arrestor; it amounts to less than 0·05 μs. For this reason the ignition voltage has, practically, the same value (impulse factor = 1) under A. C. voltage and under impulse stressing and does not exceed 1700 V (R. M. S). When the values given in Table II and the extraordinary short duration of this voltage peak (about 0·05 μs) are taken into account, this ignition voltage must be considered as remarkably low. Further, after the lapse of this short time lag, the voltage is reduced to the value of the residual voltage, which is about 1000 V crest value. Fig. 13 shows a cathode-ray oscillogram of an impulse test. The steep fronted transitory wave a of a value of 25,500 V crest value with a front duration of a 0·25 μs is transformed into wave b, with an ignition peak of about 2000 V crest value and residual voltage of about 1000 V crest value after the arrestor has been connected up. It is worthy of note that the wave b which persists after the arrestor is connected up is, practically, independent of the crest value and shape of the incoming wave a. This fact was proved by tests in the impulse wave testing plant, with transitory waves of 100—300 kV crest value in which the limiting capacity of the arrestor was never attained, in any one case. Taking into account the relatively high discharge capacity of 750 A crest value with impulse waves of 1 μs front duration and of 30 μs half-value duration it can be asserted that the arrestor works perfectly and in a manner similar to that shown in Fig. 13, under direct lightning strokes and under transitory waves with reflected voltages up to about 400 kV crest value. It may be added that, according to the new Swiss regulations for the testing of arrestors for service voltages up to 1000 V, an impulse wave of 50 kV crest value and a discharge capacity of 100 A crest value

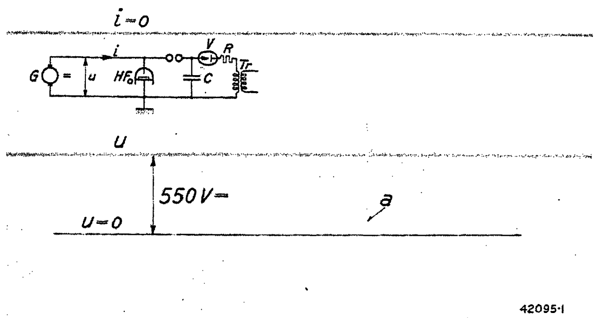


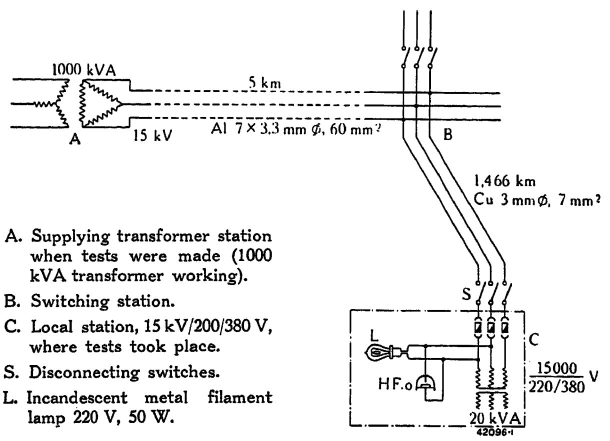
Fig. 14. — Oscillogram of terminal voltage u and of current i in arrestor, recorded during an impulse test.

The arrestor is connected to a 550-V D. C. system.
Amplitude of impulse wave 50 kV crest value. Discharge current through arrestor 100 A max. (1/35 μs).

a. Arrival of wave and arrestor ignition.
i=0, i. e. instantaneous extinction.

are given as sufficient. *Due to its properties, the arrestor type HFo gives efficient protection against dangerous over-voltages, for all parts of the plant, such as insulators, windings, apparatus and indoor installations.*

The reliability in service of the apparatus was proved by numerous and thorough tests in which the impulse voltage was imposed on the service voltage already applied; in these tests various sources of power were resorted to, as for example, D. C. generators or mutators of big output, in the case of D. C. and direct supply from generators and transformers, in the case of A. C. Fig. 14 shows an oscillogram recorded in an impulse test of this kind under 550 V D.C. and an impulse wave of 50 kV; although



A. Supplying transformer station when tests were made (1000 kVA transformer working).
B. Switching station.
C. Local station, 15 kV/200/380 V, where tests took place.
S. Disconnecting switches.
L. Incandescent metal filament lamp 220 V, 50 W.

Fig. 15. — Test on a 15-kV overhead system made on an arrestor Type HFo, to determine its properties as a voltage limitor.

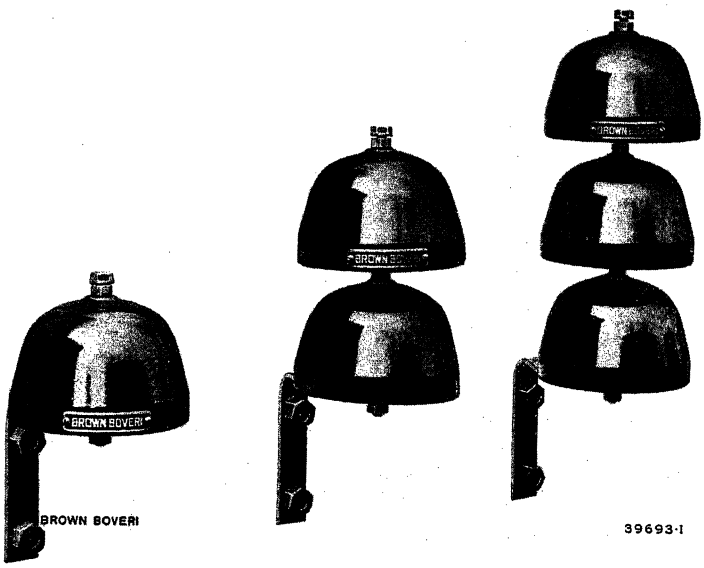
the impulse current attains 100 A crest value (1/35 μs) it could not be recorded with a magnetic type oscillograph element as the duration was too short. On the other hand, a voltage oscillation of the plant with a frequency of 1800 cycles is shown clearly, just after the impulse, which oscillation vanishes already after 0·0008 s. Thus, the plant up to the arrestor, is in no way stressed by the impulse voltage which would, otherwise have led to trouble.

The advantageous test results coincide with a large number of practical results recorded with this arrestor, in different countries. Mention should be made of tests on systems to find out the properties of the arrestor as a voltage limiter which were organized by the testing laboratories of the French Ministry of Agriculture. Fig. 15 shows the diagram of the system used for these tests. The transformer supplying power is of 1000 kVA output at 15 kV. In the substation C at a distance of about 6·5 km, the local transformer was shunted and the arrestor connected up directly behind the high-voltage fuses in parallel with a metal-filament incandescent lamp for 220 V, 50 W, the disconnecting switch being, to begin with, in the open position. After this, the disconnecting switch was closed. The testing conditions and results are given in the following table.

Fuses of	Rated current A	Ignition of arrestor	Observations
1 × Ag 0·2 mm diam	3·5	Instantaneous	Lamp intact
2 × Ag 0·15 „ „	5	„	„ „
3 × Ag 0·15 „ „	7·5	„	„ „

The fuses melted without any phenomena being recorded on the low-voltage part. The sensitive incandescent lamp behind the arrestor was unharmed. There were no marks of burns on the arrestor electrodes and its resistance elements were in perfect condition.

500 V is the highest rated voltage allowable for arrestor type HFo, this both for A. C. and D. C. For higher voltages, several arrestors in series are used, being bolted together in the form of a column (Fig. 16). They are put up in the same way as single units. In a multi-phase system, an arrestor per phase is used and if the neutral is not directly earthed it must also be earthed through an arrestor. In regions liable to storms or frequent discharges of lightning the over-voltage arrestors are very useful on overhead lines as they prevent service interruptions due to flash-overs on insulators. It generally suffices to put the arrestors on the leads into the station building, the arrestors being designed for outdoor erection.



a b c

Fig. 16. — Construction of the HFo, type of arrestor for higher service voltages.
a. Up to 500 V D.C. or A. C. b. Up to 800 V D.C. or A. C. c. Up to 1200 V D.C. or A. C.

VII. SUMMARY.

If the problem of protection against over-voltages is studied with the help of investigations made on storm phenomena and the statistical data available on trouble occurring on systems, the conclusion is reached that plants must, chiefly, be protected against over-voltages due to earth faults and over-voltages due to storms. Other causes of over-voltages are not so dangerous for high-voltage material which is properly designed. Earth faults on one phase are the most frequent form of trouble and the results thereof can only be successfully overcome by using extinguishing coils which are being employed more and more extensively to-day, on high-voltage networks. Very high over-voltages result from direct lightning strokes and these generally cause flash-overs on the insulators. Direct lightning strokes are, relatively, rare, however, while indirect lightning strokes are much more frequent and may cause dangerous over-voltages in systems up to 37 kV rated voltage. Resorbit arrestors are an efficient protection against these over-voltages, as their ignition voltage, ignition time lag, discharge capacity, extinction capacity and above all residual voltage have all been studied with this end in view. The numerous tests carried out in the works and with the big surge generator of the Swiss Electrotechnical Society show that this arrestor has an efficient protective value even in plants which are relatively poorly insulated.

As regards the protection of low-voltage networks against over-voltages, it can be said that an over-voltage protective apparatus is very useful, especially in overhead transmission lines, despite the relatively high break-down resistance to impulse voltages of the line material generally used. The insulation of overhead lines is generally far superior to that of the material used indoors and for this reason certain over-

voltages cause dangerous disturbances and often service break-downs in the indoor plant. The low-voltage arrestor type HFo reduces very high transitory wave voltages to values which are no longer dangerous to the plant and it provides a very complete protection of the plants against over-voltages. At the same time, this apparatus works as a voltage limiter and this is especially useful in case the high-voltage side gets into accidental contact with the low-voltage system.

The very numerous and favourable service results have gone to confirm the satisfactory results of laboratory tests carried out both during the development of these arrestors and their official testing.

(MS 937) *Dr. J. Kopeliowitsch. (Mo.)*

NOTES.

Individual electric drive of flyers.

Decimal index 621. 34: 677. 052. 24.

EXPERIENCE has proved the advantages of individual electric drive as compared to line-shafting drive, both from a technical and economical point of view. These advantages which are generally recognized to-day can also be extended to the preparatory stages of spinning, among others, notably, to the drive of flyers. Belt drive over a jockey pulley by means of a squirrel-cage motor built on to the flyer headstock is especially favourable. This arrangement has the great advantage over all others, that it takes up little space. The iron bracket which carries the motor can be fitted to any headstock and secured thereto by two bolts. This bracket also carries the switchbox and jockey pulley, the whole being easy to mount. The jockey pulley runs on ball bearings and acts as a belt fork, as well. It is placed loose on a shaft carried by the bracket and is connected to the stop rod of the flyer. After the switch has been closed, it is only necessary to displace the belt in order to start exactly as in any other belt drive. Starting is smooth and the flyers can be inched into the desired position for threading.

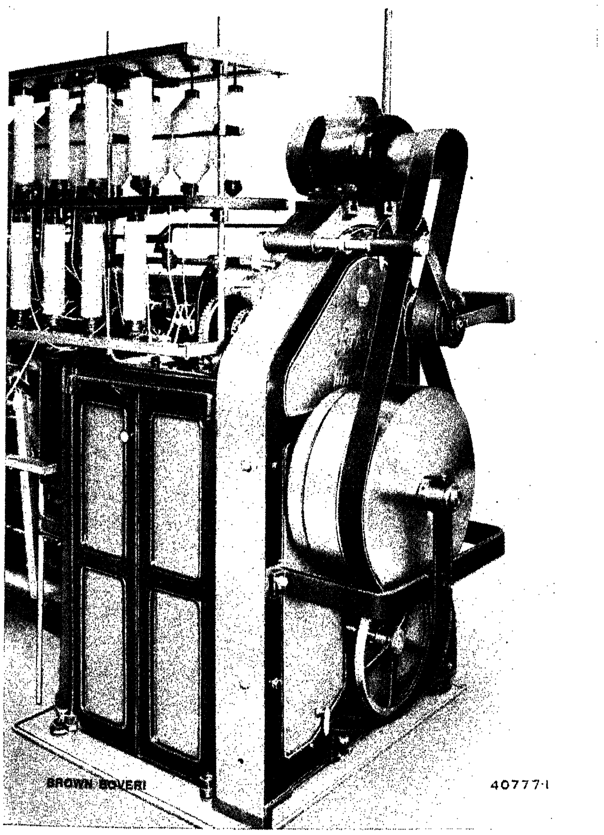


Fig. 1. — Individual drive of intermediate flyers by means of totally-enclosed externally-cooled motors Type MUe.

Service requirements are, thus, fulfilled in a natural manner and by simple means, when this drive is used. These drives are more reliable in operation and easier to handle than geared drives which call for special starting windings or resistances and special switches in order to attain a smooth start, besides demanding more supervision.

Squirrel-cage motors of the multi-slot type are used, usually four-pole motors, that is to say fast running economical machines. The design is of the externally-cooled, totally-enclosed type so that no dust can reach the motor and the only attendance called for is occasional inspection of the grease-lubricated ball bearings.

The built-on switchboxes with their thermal releasing device protect the motors, perfectly, against over-heating.

The drives described can be built on to both new flyers and on to old ones formerly driven by transmission shafting, there being no difficulty about this. Thus, existing plants can be transformed to electric drive without it being necessary to alter the machines. Individual drive should be adopted, exclusively, in all new plants. The expenses incurred thereby are approximately balanced by saving in transmission shafting and in building outlay. To this must be added the series of fundamental advantages enjoyed by plants equipped with individual drives, such as easy supervision of the sheds, less dust, greater service reliability and more economical production.

(MS 957) *H. Wildhaber. (Mo.)*

Big generators for plants overseas.

Decimal index 621. 313. 322.

THE demand for electric power in the Island of Tasmania, south of Australia, is constantly increasing and this is especially so for the mining territory on the west coast of the island. There are two hydro-electric power stations in operation: — Waddamana producing 70,000 H. P. and Shannon station, producing 15,000 H.P., and, a short while ago, the Hydro-Electric Commission of Hobart was obliged to start work on a new power scheme, to relieve the existing stations.

The new high-head hydro-electric plant Tarraleah utilizes the Derwent River, and when complete will generate about 100,000 H.P. The head-race channel intake is about 20 km below the point where the Derwent flows out of Lake St. Clair. This channel is 25 kilometres long and follows, approximately, the course of the river itself. It leads to the water chamber from which the penstock, about three kilometres long, with a drop of about 300 m carries the water to the power house. The tail-race channel opens into the Nive River which flows close by.

Brown, Boveri & Co., Ltd., were given the order for the three horizontal-shaft generators of the three 20,000-H.P. sets to form the first development stage of this power scheme. These are driven at 428 r. p. m. by double Pelton-wheel type turbines having two nozzles per wheel. The generators give three-phase current at 50 cycles and are each of 18,750 kVA, 11—12 kV terminal voltage, p. f. 0·8. Under a wattless load, with zero p. f. leading, they can each deliver 12,000 kVA.

The generators are of completely-enclosed design, the cooling air being carried in and led off through ducts let into the machine-hall floor and opening to the outside air. Removable shields allow a part of the air being led off to be driven into the machine-hall, instead. The stator is of the welded type; it rests on stools which are also welded and which are secured to the foundations. The

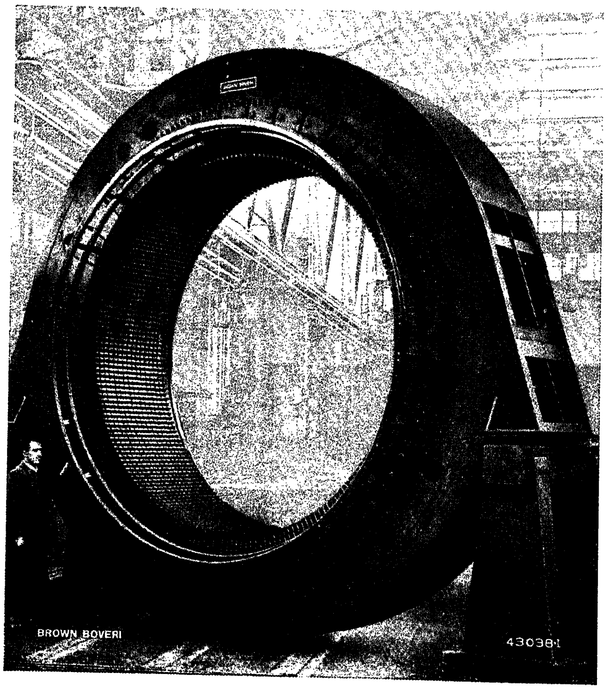


Fig. 1. — Stator of a generator with laminations already set in, 18,750 kVA, 11 kV, 428 r. p. m., 50 cycles.

illustration shows a stator with its complete laminations in the Baden shops.

Each generator weighs about 90 t of which 48 t is the weight of the rotor which has a flywheel effect of 210 t m^2. The stator is in two parts to facilitate transport. For the same reasons the rotor can be divided into two parts after removal of field poles and shaft.

The rotor is carried in two water-cooled pedestal bearings and the turbine has also an external bearing. One shaft end of the generator has a coupling flange to allow of the generator being rigidly coupled to the turbine. The other generator shaft end carries the overhung main exciter. An auxiliary exciter to supply the field of the main exciter is built into the main exciter, forming part thereof.

Brown Boveri delivered as accessories the complete equipment for automatic voltage regulation for all the generators, the automatic regulators having the well-known rolling contact sectors; they also delivered field-suppression switches and electric temperature-measuring equipments for eight different measurement points on each generator.

(MS 966) *H. Vetsch. (Mo.).*

Electro-hydraulic thrustor as brake lifter on a high-power crane plant.

Decimal index 621. 34 : 621. 866. 5.

AUTOMATIC stop brakes for hoists, cranes and conveying plants, etc. have generally been equipped with brake-releasing electro-magnets, up till to-day. These releasing magnets have a movable core which is attracted if the coils of the magnet are put under voltage and cause the band or shoe-type brake to be lifted, i. e. released. If the voltage fails, a weight or a spring acts to apply the brake. It often happens that big plants with high-power driving motors cannot be equipped with brake-releasing magnets as the latter are unequal to the task of lifting the brakes; in such cases motor brake releasers have been used.

One great disadvantage of brake-releasing electro-magnets is the abrupt braking they occasion, which puts

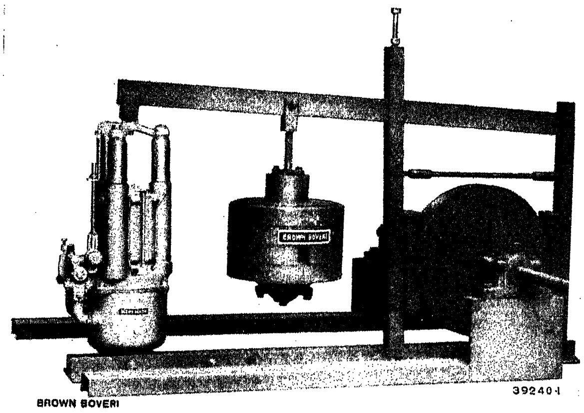


Fig. 1. — Electro-hydraulic thrustor for a lifting duty of 2200 cm/kg; working as a brake lifter.

considerable strain both on the brakes themselves and on the whole crane or winding gear and shortens the useful life of the equipment. The A. C. brake-releasing magnets absorb a very strong current surge at the moment of circuit closing and, for this reason, it is not possible to make the coils of these magnets absolutely defect proof. If, when attracted, the magnet core is prevented from accomplishing its complete travel on account of too great a mechanical load opposed to it, or because the pull-rod has somehow become wedged, the heavy current surge, persists, and the coils burn out. This often leads to service stoppages with their undesirable consequences.

The electro-hydraulic thrustor developed by Brown Boveri works on a new principle and is exempt from the above-mentioned drawbacks; it has given proof of its great reliability under very severe service conditions with frequent braking operations.

The electro-hydraulic thrustor is mainly composed of a centrifugal pump driven by a small motor. This pump drives oil under pistons which are, thus, displaced vertically upwards (Fig. 1). This is, therefore, a lifting device driven by a small motor. The heavy current surges mentioned in connection with electro-magnets are eliminated, here, and there is no difficulty in making the motor driving the centrifugal pump absolutely reliable. If the electro-hydraulic thrustor is mechanically overloaded, i. e. if it is called on to produce greater lifting work than that corresponding to its rating, the lifting pistons move slower or come to

a stop; the centrifugal pump then simply churns the oil but does not displace it, and there is no damaging overloading of the motor.

The electro-hydraulic thrustor works quickly and smoothly (without shocks). A regulating device which is operated simply, from without, can be so adjusted that the

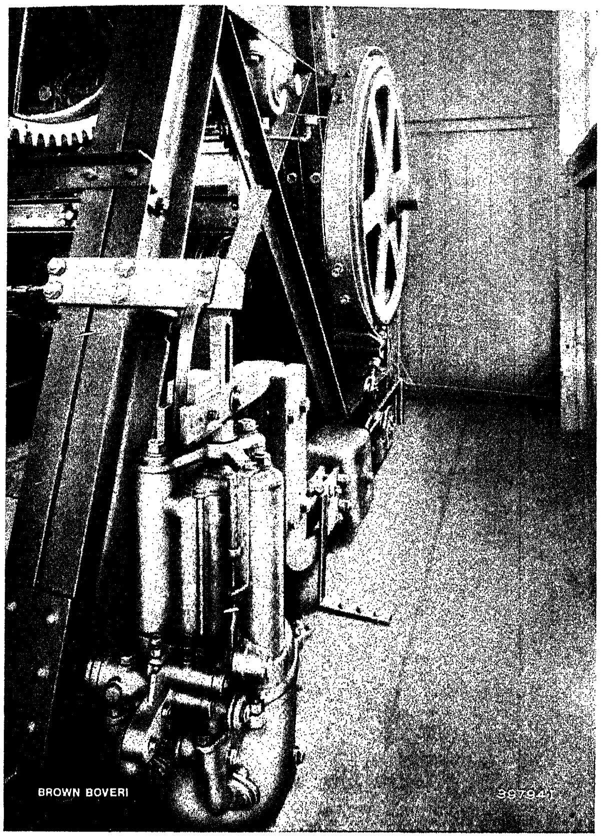


Fig. 2. — Electro-hydraulic thrustor working as a brake lifter in a high-power crane plant.

brake is quickly applied, as is necessary in hoists, in order to prevent the load falling. On the other hand, if big loading bridges are being stopped, braking must not be abrupt, but gradual. The hydro-electric thrustor allows of setting the brake-application time over a considerable range. In every case the electro-hydraulic thrustor works without shocks which preserves the whole plant, while reducing brake wear to a minimum.

To summarize, the electro-hydraulic thrustor is superior to the brake-releasing magnets in the following points:—

(1) Operation is devoid of shocks and is independent of the load on the thrustor.
(2) It has a free fall damping character which can be set from without, simply and over a wide range. The setting, once made, is maintained indefinitely.
(3) The lifting work of the thrustor is the same under all service conditions, whether the apparatus is left switched in continually or whether there are 120, 600 or more switchings per hour.
(4) The driving motor cannot be overloaded by too heavy mechanical stressing of the thrustor.
(5) Low power consumption.
(6) Compact design.
(7) Nearly no supervision.

Fig. 2 shows the electro-hydraulic thrustor as a brake lifter in a high-power crane plant. This is a grab-crane equipment for 50 kW and 400 switchings per hour. This equipment with the thrustor as brake lifter has been in service for a long time and results are most satisfactory in every way. The engineers-in-charge and crane operators appreciate the smooth operation, devoid of shocks, and the reliability of the thrustor as compared to the former brake-releasing magnets. No overhauls or alterations of the setting once made have been called for since the plant was put to work, this despite the fact that the thrustor has been in use for about six months and under about 400 switchings per hour.

(MS 969) *E. Altschul. (Mo.)*

Heavy-current mutators for a new aluminium electrolytic plant.

Decimal index 621. 314. 652. 2 : 621. 357 (494).

THE battle between copper and aluminium has turned, decidedly, in favour of the latter, partly on account of its valuable properties, when used alone or in the form of alloys, as a building material for light metallic structures, as a conductor in overhead transmission lines or bus-bar plants and also partly on account of exchange difficulties encountered by certain countries; the amount of aluminium used is greater every year.

Brown Boveri recently booked an order for the complete electrical equipment of a mutator station for a new aluminium electrolysis plant, for the Aluminium Industrie A.-G., Neuhausen (Switzerland). The equipment comprises eight *heavy-current mutators to deliver a total of 44,000 A at 600 V, corresponding to an output of 26,400 kW,* with all accessories. The mutator plant will be put up in the Rheinfelden works of the above concern and will be built by Brown Boveri, Mannheim.

As the general diagram of connections shows, each pair of mutators forms a set to give 11,000 A and each of these sets is supplied from one transformer. The three-phase power is supplied through two 18,000-kVA, 125/20/5-kV three-winding transformers with built-in tap changers, and regulated on the 20-kV side. These feed the four 9000-kVA mutator transformers. The constant-current system according to which all industrial electrolytic processes work (large number of baths or furnaces connected in series to form a circuit supplied with current which must be of constant strength, and the voltage of which must, therefore, be variable over a wide range) is, really, difficult to adapt to the characteristics of the ordinary three-phase power production and distribution which is characterized by constant voltage with variable current strength. This difficulty was overcome, however, by means of a regulating system, developed by Brown Boveri in collaboration with the experts of the Aluminium-Industrie A.-G., Neuhausen, which has found a wide field of application since then. According to the method of regulation in question, the constant three-phase voltage is adapted to the variable electrolytic voltage required by means of regulating transformers and hand-operated on-load tap changers, this in connection with automatic grid control of the mutators which supplies the necessary fine-voltage regulation between two steps of the regulating transformer.

With the object of simplifying big electrolytic mutator plants and of making them cheaper, the suggestion was put forward, lately, that the regulating transformers and tap changers might be done away with altogether and that the whole range of voltage regulation called for

regulated by mutator grid control. The successive reductions of the D. C. voltage (reduction of the watt load) are then effected by increasing the displacement of the anode ignition point, but this does not result in a reduction of the three-phase kVA load supplied, on the contrary the increasing deterioration of the power factor brings with it a corresponding increase in the load of the three-phase supply due to the rise of wattless power. As, now, the range of D. C. voltage regulation has to be in the ratio of 1 to 2 up to 1 to 3, in the majority of cases, it is easy to understand that as long as the electrolytic load forms a considerable portion of the generator load, grid regulation alone cannot be applied until extinguishing grids have been developed which are absolutely reliable for vapour-filled mercury cathode valves. If the range of voltage regulation is smaller (20—30 %), it is possible that a thorough investigation of the conditions may show that wattless-load condensers can take the place of on-load tap changers.

The waviness of the mutator current is completely suppressed by the inductivity of the heavy aluminium bars laid between the mutators and the furnace hall, or also by additional choke coils, which is shown clearly by oscillograph records. However, with the usual double or triple six-phase connections used, higher harmonic waves occur in the three-phase supply system which, under certain circumstances, may have a noticeable influence on the transmission line and generator. The possibility of this occurring, however, in no way justifies the present-day tendency to put in 12-phase transformers, with very complicated windings, and which are insufficiently short-circuit proof, in the place of the simple and thoroughly proven six-phase transformers which can be said to be absolutely short-circuit proof. Considering that the very severe stressing to which a mutator transformer is subjected when a valve fails is the greatest strain which can be put on this part of the equipment and also that the construction of 12-phase transformers must, necessarily, be more expensive for the client, Brown Boveri decided to continue to use six-phase transformers, as they are much more reliable, and to counteract the effect of the mutators on the three-phase supply system by other methods. In order to alleviate the apprehensions of the power supply company, in the present case, a new connection with a $\pm 15^\circ$ phase combination of the primary windings was adopted for the mutator transformers of the new aluminium plant. This method of connection produces a displacement of phase position of the six-phase systems of the two transformers in parallel amounting to 30°; thus, for each pair of parallel-connected transformers a purely 12-phase connection is created with the result that the 5th and 7th, 17th and 19th etc. higher harmonic are eliminated from the total primary current. This special system of connections of the mutator transformers fulfils the desires of the maker as regards simplicity, that of the buyer regarding low cost and, finally, that of the power producing company as regards higher harmonics. Anode choke coils have not been put in so as to simplify the heavy bar leads between transformers and mutators. Each mutator transformer, however, is built with six six-phase secondary windings for direct-connecting to two 18-anode mutators. In order to master the enormous short-circuit currents entirely, which occur in plants of this size, these heavy-current mutators are equipped with Brown Boveri patented grid protection combined with high-speed breakers on the D. C. side and quick-acting water breakers on the three-phase side. The thoroughly reliable absorption choke coils, which relieve the current-carrying anodes considerably, also play a part in increasing the service reliability of the plant. A special three-phase forming bar is put in to allow of easy forming and reforming. This bar can be supplied from the 5-kV tertiary winding of the regulating transformers or from an independent source of current; forming is then carried out by changing over the primary winding of the mutator transformers in connection with the grid control.

Brown Boveri were also entrusted with the delivery of the whole switchgear plant inside the mutator building including the 5-kV part of the plant and the station requirements for the different secondary services of a modern

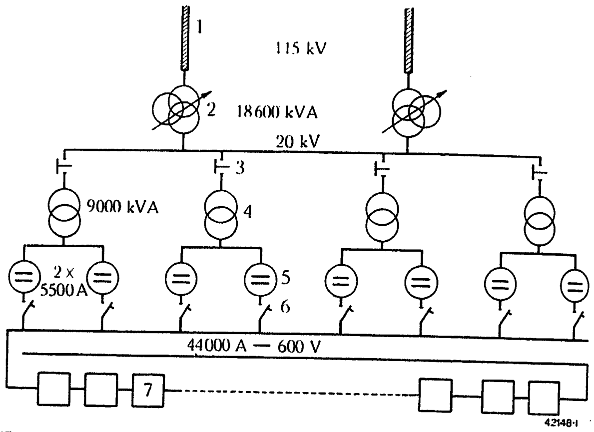


Fig. 1. — General diagram of connections of the electrolytic mutator plant 44,000 A, 600 V.

1. Oil cable 115 kV.
2. Regulating transformer.
3. Water circuit breaker.
4. Mutator transformer.
5. Mutator.
6. Quick-acting breaker.
7. Aluminium furnace.

aluminium plant. The material delivered includes all the compressed-air-operated water circuit breakers and the D. C. quick-acting breakers, the cooling devices for mutators and transformers as well as the complete connecting bars made of aluminium.

(MS 971) *A. Danz. (Mo.)*

The light motor coach Ce $^2/_4$ No. 787 of the Berner Alpenbahn Gesellschaft (Berne-Lötschberg-Simplon).

Decimal index 621. 335. 4 (494).

LIGHT motor coach No. 787 of the Berner Alpenbahn Gesellschaft was put into regular service on the 18th of November 1935; a similar unit No. 202 has been running since May 1935 on the Swiss Federal Railway system having covered to date about 75,000 km. While the object to be fulfilled by the new coach is similar to that of the Swiss Federal Railway coach, namely improvement of traffic conditions on certain line sections, it differs from the latter in some characteristic points. To begin with, its highest travelling speed is limited to 90 km/h and it is designed to draw one or several trailer coaches. It is specially adapted to the Bern-Schwarzenburg line section which has many curves and gradients. In order to meet these very unfavourable line conditions, this coach is equipped with a special type of bogie built by the Schweizerische Industrie-Gesellschaft, Neuhausen, and which is designed to assure good running on curves. Although the distance between bogie axles, 3·4 m, is extraordinarily big for a line section like this one, the coach takes all curves in irreproachable manner; this is due to the bogies being equipped with axles which are adjustable to curves and which are constrained to take up radial positions on the curves.

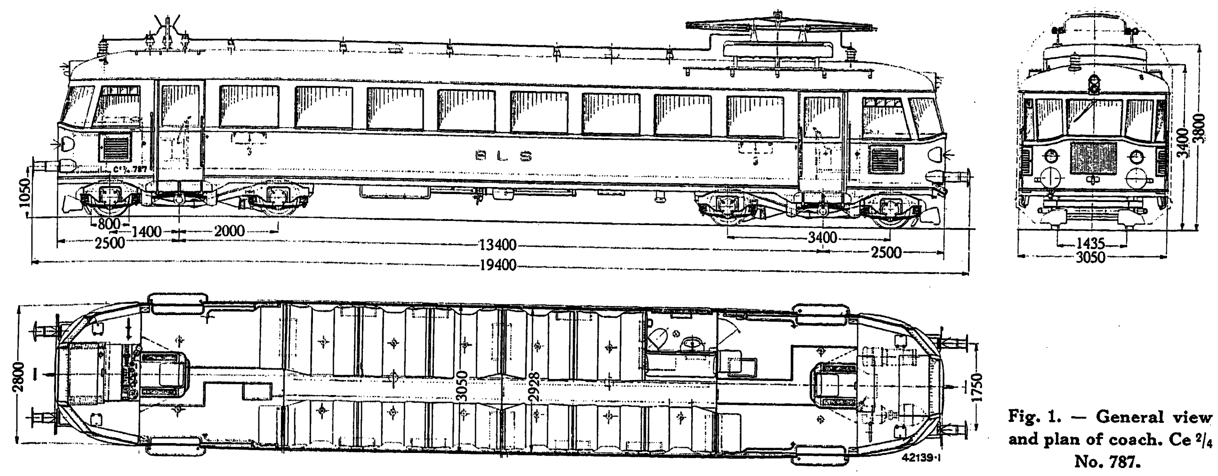


Fig. 1. — General view and plan of coach. Ce 2/4 No. 787.

This newly-developed bogie design requires that the two driving motors should be placed one on each bogie and not both on the same bogie. As, further, good adhesion of the motor coach is an essential condition, here, where a maximum gradient of 35 ‰ has to be negotiated when drawing a trailer load, the two motors are connected electrically, in parallel. There is an electrically controlled ten-step cam type of controller for regulating the speed of the coach, while, the electric short-circuit braking with external excitation is provided for not less than 50 regulating steps, the advantages of which show in the braking action, which is quite free of jerks and very smooth. The coach is for one-man control and the operation of the electrical apparatus is made correspondingly simple. A simple contact maker is used to change the speed, so that with a single handwheel it is only when electric braking is being used that it is necessary to rotate the wheel through a switching angle of over 50°. The control is in constant connection with the safety apparatus of Brown Boveri design.

The main characteristics of the light motor coach No. 787 are:—

Maximum speed of coach		90 km/h
Total one-hour rating at 50 km/h		280 H. P.
Number of passengers seated		65
Number of passengers standing		50
Total number of passengers		115
Weight of mechanical parts	about	24 t.
Weight of electrical equipment	„	8,5 t.
Tare	„	32,5 t.
Diameter of driving and running wheels		800 mm.
Ratio of reduction gear		1 to 3·27

A more detailed article on the characteristics of this coach will be published later.

(MS 972) *W. Lüthi. (Mo.)*

Air-blast high-speed circuit breakers.

Decimal index 621. 316. 57. 064. 241.

THE "Union Cotonnière" Company, in Ghent (Belgium), recently started up a new weaving mill. The substation which supplies the weaving mill with electric power is equipped with a transformer the high-voltage side of which is directly connected through a short cable length to the bus-bars of the power station of the town of Ghent. Apart from the impedance of the connecting cable, which is so low, that it can be disregarded, there are no other impedances between the power station and the substation which would act to reduce the strength of the current in the case of a short circuit on the high-voltage side of the substation. A short circuit of this kind would, therefore, react violently on the power station itself. Two primary factors dictated the choice of the main circuit breaker protecting the plant:— circuit breaking had to be as rapid as possible and the rupturing capacity of the breaker high, on account of the big output of the power station; it had to be possible to close the breaker on the strongest short-circuit current met with. In consideration of the fulfilment of these conditions, the "Union Cotonnière" chose Brown Boveri air-blast quick-acting circuit breakers for their substation because they are especially suitable for conditions like these.

The new Brown Boveri air-blast quick-acting breaker is characterized by its high rupturing speed, one which has never been attained, so far, by any other design of breaker. It certainly incorporates the distinctive qualities of a quick-acting breaker.

No details of the breaker design are gone into, here, save that the air-blast quick-acting circuit breaker is mainly composed of a power breaker proper which extinguishes the arc and of a disconnecting air switch which takes care of the definite opening of the current circuit. The circuit is closed by closing this air disconnecting switch, which operation is carried out by the breaker handwheel.

An idea of the switching speed of the breaker is given by the rupturing time. In systems with a frequency of 50 cycles, the rupturing time amounts to 0·015 s, counted from the initiation of the rupturing movement of the air-blast valve up to the completion of the rupture i. e. complete extinction of the arc. The duration of the arc proper does not exceed half a cycle, at the most.

In order to assure selectivity in circuit breaking, one of the circuit breakers has been equipped with the new Brown Boveri series relays. This type of relay combines high thermal and dynamical short-circuit strength with a remarkable precision. It can be set either for instantaneous tripping or for a definite time setting. In the latter case, the time setting device can be blocked for a given current strength so the relay only trips the breaker with the time setting adjusted to, for currents which are lower than this strength, while it trips the breaker instantaneously if a short circuit occurs the current of which exceeds the blocking current. The definite time setting adjusted to is guaranteed with a margin of 0·1 second. If the relay is set for instantaneous tripping in case of short circuit, the rupturing

time attained for the breaker and relay together is the minimum of what can be attained in this field to-day. If, on the contrary, it is desired to eliminate instantaneous tripping altogether, it is possible to reduce the grading of the time settings from relay to relay on the same branch line to figures considerably below the time settings possible up till to-day, this while maintaining perfect selectivity; this quality is due to the high switching speeds of the breaker and setting precision of the relay. In this way the time settings themselves can be reduced and the destructive effects of short circuits reduced.

The use of air-blast quick-acting circuit breakers combined with the new—series or secondary—Brown Boveri relays thus leads to an improvement of selective protection.

(MS 962) *J. Defreyn. (Mo.)*

Upkeep of commutators on the single-phase locomotive motors of the Swiss Federal Railways.

Decimal index 621.333.047.2:621.335.2 (494).

AT the period when the countries of Central Europe decided to use single-phase current at low periodicity for the electrification of their main lines — a decision reached more than twenty years ago — one of the most essential units involved, the high-power traction motor, was still in a state of evolution. Of the numerous motor designs taken into consideration, the one finally selected as the most suitable and promising was the single-phase series-wound motor with phase-displaced commutating field. However, the whole problem of commutation, of the wear of commutators and brushes, in other words, the upkeep problem, had not, at that period, reached a satisfactory solution. The commutator had to be what may be termed "nursed", in service, a condition which still holds good, to-day; they have to be ground true with carborundum and sandstone and must be turned up, from time to time.

In the early days of single-phase traction, so-called "grinding figures", that is to say the number of kilometres travelled over by the locomotive before the commutator had to be ground again, only attained values of 8000 to 10,000 and one hardly dared to hope, at that time, that by means of improvement of commutator design, selective choice of material, repressing etc. it would, finally, become feasible to allow the motors of a locomotive to run, from one general overhaul of the machine to the next, without paying them any particular attention.

Formerly, the Swiss Federal Railways reckoned with a span of three years between general overhauls, corresponding to 300,000 kilometres travelled over. To-day, this period has been extended to four years corresponding to 400,000 kilometres. The Swiss Federal Railways make statistical records on the upkeep of driving motors and, notably, of the distance the various locomotives travel over until a regrinding becomes necessary. The following figures have been taken from the latest of these statistical records on some Brown Boveri locomotives.

Locomotive Type 2 C_o 1 90,000 locomotive kilometres
 „ „ 2 D_o 1 203,000 „ „

In a few cases, the following exceptional figures were recorded for the express locomotives of type 2 D_o 1:—

Maximum figures, locomotive Type 2 D_o 1, No. 10,901
536,000 locomot. kilometres

Maximum figures, locomotive Type 2 D_o 1, No. 10,902
548,000 locomot. kilometres

Maximum figures, locomotive Type 2 D_o 1, No. 10,903
604,000 locomot. kilometres.

It should be noted that these figures stand for locomotive-kilometres and not for commutator-kilometres; the latter being often published by other firms in order to attain figures which are two or three times greater.

It can be confidently expected that, in future, a large number of Brown Boveri locomotives will, at least, be able to run from one general overhaul to the next without it being necessary to touch the commutators. This would, of course, help considerably to reduce the upkeep charges of the driving motors. The figures now attained for kilometres travelled over between grindings would have been deemed impossible of attainment not so long ago. If they are practical realities to-day, it is only due to careful handling and supervision of the machines by the personel of the Swiss Federal Railways, combined with improvements introduced to the design and construction of the commutators themselves, this in collaboration with the makers of carbon brushes.

(MS 955) *E. Schrœder. (Mo.).*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2):621.313.322.

THE Brown Boveri Review of July 1935, No. 7, page 147, reported on a single-phase generator which had been running in Egypt since the year 1898. Attention is drawn here to a three-phase generator of quite similar design delivered on the 11th August, 1896 to Messrs. Oederlin & Co.,

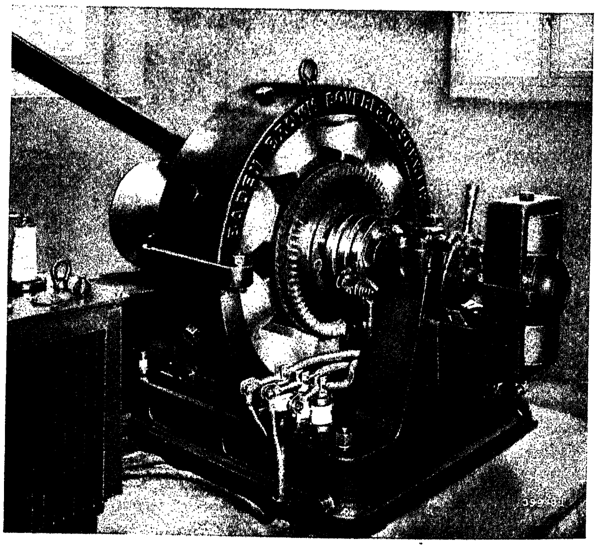


Fig. 1. — Three-phase generator 55 kVA, 200 V, 160 A, 51·3 cycles, 770 r.p.m. put up in 1896 in the works of Messrs. Oederlin & Co. Ltd., Ennet-Baden (Switzerland).

Ennet-Baden (Switzerland). This unit has been in practically continuous service since it was delivered. The generator is driven by a water turbine at 770 r.p.m. and is designed for 55 kVA, 200 V, 160 A, 51·3 cycles. Fig. 1 shows its design very clearly. The fixed magnetic field has eight poles and the rotating armature delivers its current through three bronze slip rings. The built-on exciter has an inner commutator corresponding to the design then in use.

The machine is still running perfectly to-day.

(MS 941) *Prop.*

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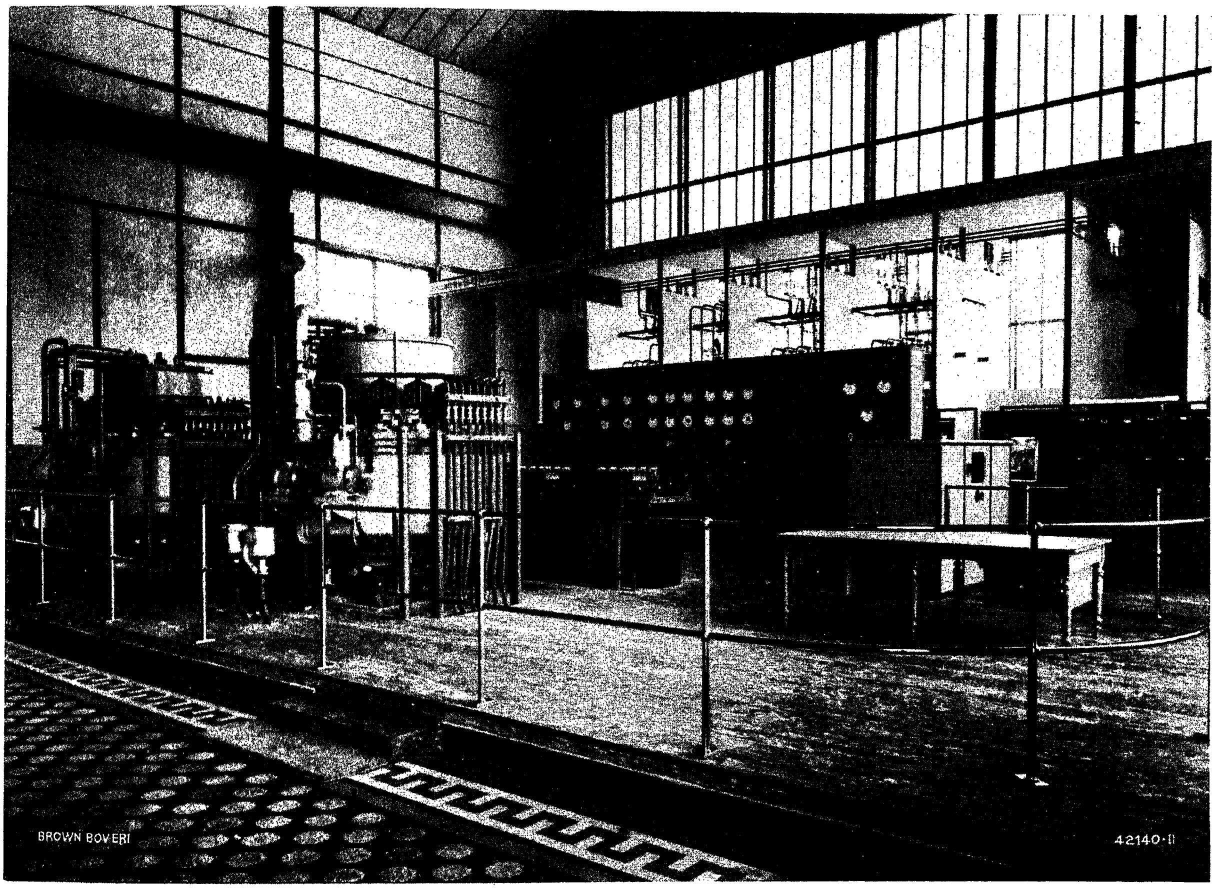
THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



THE MUTATOR PLANT OF THE USINES DE LA PROVIDENCE IN HAUTMONT (FRANCE).

CONTENTS:—

Printed in Switzerland

WATER-JET ELECTRIC BOILER

Zuckerfabrik & Raffinerie Aarberg A.-G.

Nebenbetriebe:
Melassebrennerei, Melassefutterfabrik
Kunstdüngerfabrikation
Trocknung von Rübenschnitzeln
Eigene Landwirtschaftsbetriebe

Telegramme: Raffinerie. Telephon Nr. 40 & 117
Postcheck-Konto Nr. III/2460 R/S.

AARBERG, den 29. Januar 1936.
(Schweiz)

Brown, Boveri & Co. A.G.,

B e r n .

Betr. Elektrokessel- Anlage.

In Beantwortung Ihres Schreibens vom 27. d.M. teilen wir Ihnen mit, dass der von Ihnen im Oktober v.J. unserem Garbekesselhaus angegliederte Elektrokessel bisher in ununterbrochenem Tag- und Nachtdienst zu unserer vollsten Zufriedenheit gearbeitet hat. Wir haben die Absicht, solange wir Strom zur Verfügung haben werden, mit dem Elektrokessel unsern Dampfverbrauch mitherzustellen.

Er hat die Aufgabe unsere mit Steinkohlen beheizten Steilrohrkessel zu entlasten mit ausserordentlicher Wirtschaftlichkeit und aller nur wünschbaren Betriebssicherheit dauernd erfüllt. Obgleich seine Nennleistung mit 8000 kg Stundenleistung bei 6000 KW. Stromaufnahme gewährleistet war, konnten wir vorübergehend bis auf 10000 kg gehen, ohne dass weder an der Schaltarmatur noch am Kessel selbst sich die geringste Störung zeigte.

Besonders befriedigte uns der Kessel inbezug auf die Speisewasser- Beschaffenheit. Es liegt in der Eigenart unseres Betriebes, dass wir grosse Menge Kondensat zur Verfügung haben, dass in dem Wasser aber manchmal u.zw. vorübergehend Spuren von Zucker auftreten können. Während in den kohlengeheizten Kesseln der Kesselinhalt in einem solchen Ausnahmefall unverzüglich behandelt werden muss, reagiert der Elektrodenkessel in einer betriebsgünstigen Weise durch Senkung der Stromaufnahme, ohne dass die Verdampfungsleistung sich verändert.

Der Elektrodenkessel kann dank seinen sehr gut durchgearbeiteten Kontroll- und Regelapparaten hinsichtlich Dampfspannung, Verdampfungsleistung und Stromverbrauch sich vollkommen selbst überlassen bleiben, gelegentliche Kontrollbesuche eines Aufsichtsorganes vorbehalten.

Unser Personal hat sich mit dem Kessel sehr schnell vertraut gemacht, was hervorgehoben werden muss, weil dieser Kessel der erste elektrisch geheizte Dampfkessel in unseren Anlagen ist. Die Sauberkeit der Elektrodenkessel- Anlage, ihre Geruchlosigkeit, der Wegfall jeden An- und Abtransportes von Heizmaterial und dessen Rückstände, sowie der hohe Nutzeffekt von 97- 99 % macht den Elektrodenkessel zum idealen stationären Dampferzeuger. Nach dem Vorstehenden brauchen wir seine Empfehlenswürdigkeit nicht noch besonders zu erwähnen.

Hochachtend:
Zuckerfabrik & Raffinerie Aarberg A.G.

42215

BROWN BOVERI DESIGN
RELIABLE - ECONOMICAL - STRONG

Translation of the above letter from:—

Zuckerfabrik & Raffinerie Aarberg A. G.

Aarberg (Switzerland), 29th Jan., 1936.

To Brown, Boveri & Co., Ltd.,
Berne Office.

Re:— Electric-boiler plant.

Dear Sirs,

In reply to your letter of the 27th inst., we beg to inform you that the electric boiler built by you, and installed in our boiler house, has been in continuous day and night operation since it was put in and has given us entire satisfaction. It is our intention to cover our steam consumption by means of steam generated in the electric boiler, as long as we have electric power available.

The duty of the electric boiler is to take over part of the load from our inclined-tube, coal-fired boiler, and it has done so with great economy and perfect reliability. Although its rated output is 8000 kg of steam per hour with a power input of 6000 kW, we are able to get 10 000 kg of steam per hour from it, for short intervals, without in any way damaging the electric equipment or the boiler proper.

The boiler is particularly satisfactory because of the quality of feed water available. The nature of the process work produces a big quantity of condensate, but the water often contains traces of sugar. While, with the coal-fired boiler, we are obliged to treat the boiler filling without loss of time when the said traces became apparent, the electric boiler reacts in a way which does not affect the service of the plant, namely by a slight drop in the power input without its efficiency as a steam generator being impared.

The electric boiler can be left quite to itself, thanks to the thoroughly reliable control and regulating apparatus acting on steam pressure, evaporation output, and current consumption. All that is required is an occasional inspection by a skilled operator.

Our personel got familiar with the boiler in a very short time, and this should be stressed, because this is the first electric boiler to be put into our works. The cleanliness in operation, noiselessness, elimination of any conveyance, to and fro, of fuel and its waste products combined with the high efficiency attained of 97—99% all go to make the electric boiler an ideal stationary type of steam generator. The above appreciation should suffice, without further words, to prove what a recommendable type of apparatus it is.

Yours faithfully,
Zuckerfabrik & Raffinerie Aarberg A. G.

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIII APRIL, 1936 No. 4

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BROWN BOVERI TURBO-COMPRESSORS[1] IN MARINE AND HARBOUR INSTALLATIONS.

Decimal index 621. 635. 5 : 629. 12.

INTRODUCTION.

THE utilization and latest designs of Brown Boveri turbo-compressors on board ship and in harbour installations will be considered, namely:—

(1) Turbo-blowers for scavenging and charging Diesel engines.

(2) Turbo-blowers for boiler plants.

(3) Turbo-compressors as heat pumps in evaporating and refrigerating plants.

(4) Turbo-blowers for emptying ballast tanks in submarines and for ships with activated stabilizing tanks.

(5) Turbo-blowers for pneumatic conveying plants.

To begin with, a number of characteristic properties of turbo-compressors will be recalled, as these have to be taken into account when an installation is made with these machines.

I. FUNDAMENTAL CONSIDERATIONS.

This heading includes single or multi-stage, centrifugal or axial blowers and compressors. They may be designated as *flow compressors* in opposition to the *positive-displacement compressors* (e. g. reciprocating, rotary, Roots compressors).

It is essential that the operating characteristics of turbo-compressors should be clearly understood if they are to be properly utilized. Experience shows time and again, however, that a considerable amount of misapprehension still exists in this respect, and that much too little attention is paid to the properties of turbo-compressors in so far as they differ from those of reciprocating machines[2].

In particular, the following points should be exactly known:—

(a) Limitations, i. e. within what pressure and volume limits are turbo-compressors an economical proposition.

(b) Influence of the resistance of the system on the operation of turbo-compressors.

(c) The fundamental advantages of turbo over reciprocating compressors.

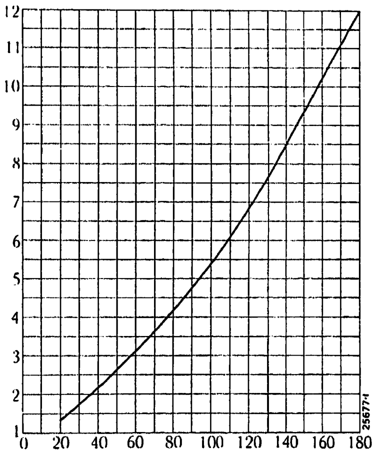


Fig. 1. — Smallest indrawn volumes in function of the pressure ratio for turbo-compressors for air under normal conditions.

Abscissæ: volume of indrawn volume of air in m³/min at 15 ° C, 1·0 kg/cm² abs, specific weight $\gamma = 1 \cdot 185$ kg/m³.

Ordinates: Pressure ratio (delivery to inlet pressure). With gases other than air or for other suction conditions, account must be taken of the differences of the specific weight.

Example: superheated steam having a specific weight $\gamma_{steam} = 0 \cdot 45$ kg/m³ is to be compressed from 1·0 to 4·0 kg/cm² abs. Pressure ratio $\frac{p_e}{p_a} = 4 \cdot 0$, $Q/_{min}$ for air = 76 m³/min. The ratio $\frac{\gamma_{air}}{\gamma_{steam}} = \frac{1 \cdot 185}{0 \cdot 45} = 2 \cdot 65$. Hence, the smallest volume for steam under the conditions considered is $76 \times 2 \cdot 65 = 200$ m³/min.

(a) *Limitations of turbo-compressors.*—Turbo-compressors are inherently suitable for delivering or compressing relatively large volumes under moderate pressure ratios. The greater the pressure ratio (i. e. ratio between pressure after and before compression) the greater becomes the smallest volume for which it is still possible to construct a turbo-compressor. Fig. 1 shows, for different pressure ratios, the smallest volumes for which it is advisable to build these machines under normal conditions. It is evident that exceptional cases can arise, for which they can be employed with advantage for still smaller volumes, e. g. whenever oil contamination must be avoided, or very little space is available, etc. It must not be overlooked, however, that the power consumption of a turbo-compressor is then less advantageous than that of a positive-displacement compressor.

---

[1] The term turbo-compressor is utilized here in its widest sense, and refers to all possible pressure conditions.

[2] The complete theory of turbo-compressors has appeared in a number of publications, one of the best of these being the series of articles in French or German which were published in the Revue BBC or BBC Mitteilungen in 1919 and 1920.

The pressure ratio which can be produced by a single impeller is generally dependent on the maximum permissible peripheral speed, which is limited by the allowable stresses in the materials employed. As a general rule, peripheral speeds of 250—275 metres per second are not exceeded except for quite exceptional conditions, such as ballast-tank blowers for sub-marines, for instance, where peripheral speeds as high as 350 metres per second have been reached. This means that with air at 15° C and $1 \cdot 0$ kg/cm^2 absolute (specific weight $1 \cdot 185$ kg/m^3), and a good compressor efficiency, the corresponding pressure ratio will not exceed $1 \cdot 3$—$1 \cdot 4$ under normal, and about 2 under exceptional conditions. With specially-designed rotors with radial impellers for charging airplane engines, pressure ratios exceeding 2 have been obtained per impeller. Furthermore, this pressure ratio increases with the density of the gas handled, i. e. it increases as the temperature becomes lower.

To obtain a high pressure ratio a number of impellers must be necessarily connected in series. When the number of impellers becomes considerable, considerations due to the critical speed of the shaft, render unavoidable the multiplication of the number of cylinders (Fig. 2). As a general rule, turbo-compressors are seldom employed for pressure ratios exceeding approximately 10, because the volume of air or gas, particularly in the last stages, becomes too small. Nevertheless, turbo-compressors have been built for pressure ratios of 20 and more.

(b) *Influence of the resistance of the system on the operation of turbo-compressors.*—It is essential that whenever a turbo-compressor is contemplated, the exact resistance characteristics of the system on which it will have to work should be known. The resistance or back-pressure characteristic of a system is neither more nor less than a pressure-volume curve, just like the pressure volume characteristics of a turbo-compressor; it shows for any indrawn volume the static pressure necessary to force this volume through the system on to which the turbo-compressor has to work.

It sometimes happens that complaints are made after a turbo-compressor has been installed that it does not produce the pressures and volumes for which it has been ordered. This is due to the overlooking of the fact that a turbo-compressor only delivers the volume stipulated under the required pressure when the back-pressure of the system on to which it operates exactly corresponds to the figure given for the volume when it was ordered. The right thing to do would be if those passing a contract always indicated the pressure-volume (back-pressure) characteristic of the system, just as the compressor builder supplies the pressure-volume characteristics of the machine which he measures on his test bed. If these two characteristics are drawn on the same scale on a common diagram, their intersection will show the exact conditions under which the turbo-compressor will operate on the system (Figs. 4 and 5).

It may be recalled that the back-pressure characteristics of a system can fall under three headings, namely:—

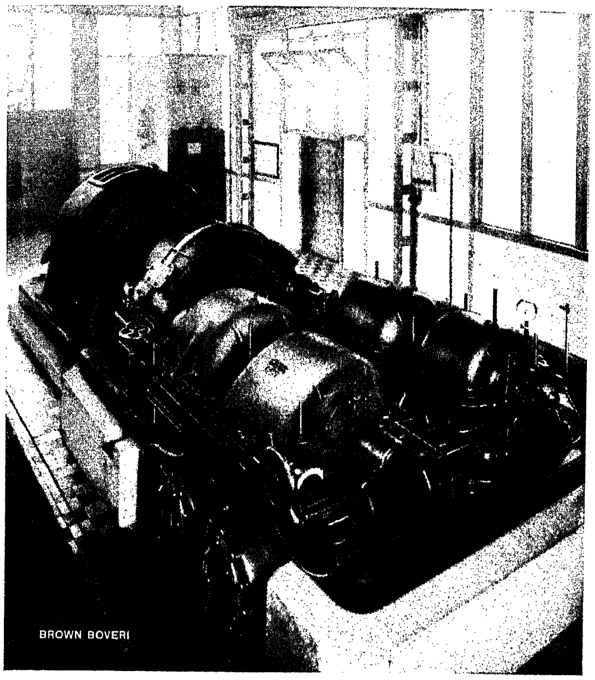


Fig. 2. — Brown Boveri two-cylinder turbo-compressor for high efficiencies and large regulation range, for supplying compressed air in shipyards.

The compressor is designed for 200 m^3/min indrawn air, pressure ratio 8, speed 8400 r. p. m., driven by three-phase motor over gearing having a ratio of 8400/1000 r. p. m.

The compressor has 13 stages, and is provided with movable diffusers and external intercooling. The 13 stages are distributed over a h.-p. and a l.-p. cylinder, which can run at different speeds, in a similar manner to marine turbines, in order to obtain best efficiencies. Brown Boveri also constructs single-cylinder turbo-compressors for these conditions, having only 9 stages but a somewhat lower efficiency.

1. *Dynamic resistances,* also called hydraulic resistances (Fig. 3a). With given, invariable cross sections, they increase approximately proportionally to the square of the volume, and consist essentially of the resistance to flow in the pipework, losses in apparatus and valves, losses due to bends, etc. An example of this form of resistance is afforded by a scavenging or charging turbo-blower, which forces air through a Diesel engine followed by an exhaust silencer or waste-heat boiler. A system of this description could be replaced by a constant-section contraction orifice: for this reason, the turbo-compressor is said to operate against a constant opening in such cases.

2. *Static resistances,* which are independent of the volume (Fig. 3b). An example is afforded when

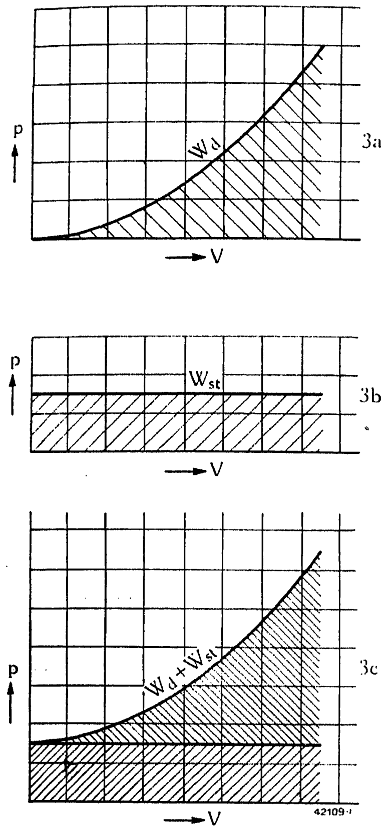


Fig. 3. — Different kinds of system resistances.

3a. Dynamic or hydraulic resistance, W_d (operation against a constant aperture).
3b. Constant, static resistance, W_{st}.
3c. Combined static and dynamic resistance, $W_d + W_{st}$.

The resistance characteristic (W_d, W_{st} or $W_d + W_{st}$) gives for different volumes V, what pressures p are necessary to force these volumes V through the system.

a gas has to be forced through a constant head of liquid. Pure static resistances do not occur in practice but only:—

3. *Combined static and dynamic resistances* (Fig. 3 c), which are obtained when the two forms of resistance just mentioned are present simultaneously. They can occur, for instance, for scavenging turbo-blowers on board submarines when the Diesel engine exhausts under water, so that the exhaust gases have to overcome, in addition to the dynamic resistance of the system, an additional back pressure due to the head of water.

If the resistance of the system undergoes a change during operation, the volume delivered by the turbo-compressor will also undergo a corresponding variation, constant speed being assumed. An example taken from practice illustrates this point:—

Complaints were made that, on board a ship, turbo-blowers supplied gave less and less air as the duration of the voyage increased, until finally very bad combustion occurred in the Diesel engines. At first sight, the fault lay with the scavenging turbo-blowers, which gave less air than the quantity for which they were ordered. A closer examination showed, however, that the exhaust ports of the Diesel engines and the silencers in the exhaust mains got more and more choked up during the voyage with solid residues, which, evidently, caused the resistance of the system to increase, day by day. Consequently, the operating point on the pressure-volume curve moved more and more to the left, so that it is understandable that with time the turbo-blowers necessarily delivered less air (Fig. 4).

Another similar case occurred on board a ship when a spark arrestor with quite an appreciable resistance was subsequently fitted into the exhaust mains. Here again, the resistance of the system was increased, whereby the volume of air delivered by the turbo-blower was diminished. The best way to counteract resistance variations of this description is to alter the speed of the turbo-blower. Consequently, motors driving turbo-blowers should be liberally dimensioned both with respect to output and to speed range.

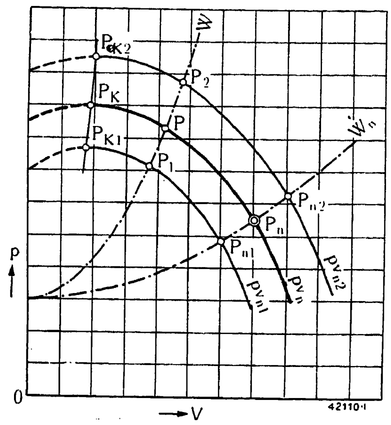


Fig. 4. — Influence of the resistance of the system on the operating point of a turbo-compressor.

pv_n, pv_{n1}, pv_{n2}. Pressure volume characteristic of a turbo-compressor at normal speed n, and at fractional and overload speeds n_1 and n_2.
W_n. Normal resistance characteristic of system.
W. Increased resistance of system.
P_n, P_{n1}, P_{n2}. Operating points with normal resistance of system and the different blower speeds.
P, P_1, P_2. Ditto, but with increased resistance of system.
P_k, P_{k1}, P_{k2}. Pumping limit of turbo-compressor.
V. Volume (abscissae).
p. Pressure (ordinates).

Whilst discussing this subject, it will not be out of place to examine, with the aid of an example, how turbo and reciprocating blowers behave under similar circumstances (Fig. 5). Let W_n be the resistance curve assumed by the purchasers: the blower would be dimensioned accordingly for the normal operating point Pn; pv_n is the pressure-volume characteristic of the turbo-blower at normal speed, and pv_{nk} the corresponding characteristic of the reciprocating blower. It subsequently turned out, that the resistance of the system was in reality much larger than assumed. It corresponded to curve W_b, and the amount of air required was v_b under a pressure p_b (operating point P_b). With constant speed, C will be the operating point of the turbo-blower, i. e. the intersection of its pressure volume characteristic pv_n with the real resistance curve W_b of the system. For the reciprocating blower on the other hand, the operating point will be B. The turbo-blower delivers, therefore, less air than required, and it produces insufficient pressure. Due to its almost vertical pressure-volume characteristics, the reciprocating compressor can overcome without difficulty the increased resistance, but under certain circumstances the pressure at B may be dangerously high. For this reason reciprocating compressors have to be always provided with pressure-relieving devices. At all events, both

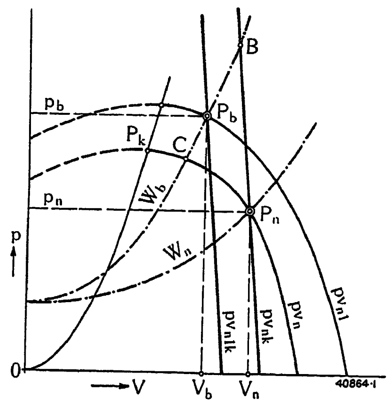


Fig. 5. — Comparison of the behaviour of a turbo-compressor and a reciprocating compressor when the resistance of the system changes.

W_a. Computated resistance of system.
W_b. Resistance subsequently obtained in reality.
P_n (p_n, V_n). Point for which the compressor was determined.
P_b (p_b, V_b). Real operating point.
pv_n, pv_{n1}. Pressure-volume characteristics of turbo-compressor at speeds n and n_1.
pv_{nk}, pv_{n1k}. Ditto for reciprocating compressor.
P_k. Pumping limit of turbo-compressor.

the pressure and volume at B are higher than necessary, with the result that the power consumption of the reciprocating compressor has an extremely prejudicial effect on the overall efficiency of the plant. In order to obtain operating conditions corresponding to point P_b, the speed of the turbo-compressor must be increased (pressure-volume characteristic pv_{nl}), whereas that of the reciprocating compressor must be reduced (curve pv_{nlk}).

This example also serves to recall a very valuable property of turbo-compressors, namely that they can never produce excessive pressures—as it is the case with reciprocating compressors—and consequently do not require any safety devices in this connection.

(c) *Inherent advantages of turbo-compressors over reciprocating compressors.*— Although these advantages are generally known, they can be briefly summarized as follows:—

1. *Considerably smaller dimensions and weight.* Both of these factors are very important on board ship. Due to the continuous acceleration and retardation of the masses, mean piston speeds do not exceed 10 m/s with reciprocating compressors, whereas with turbo-compressors peripheral speeds up to 275 m/s (in exceptional cases even up to 350 m/s) can be allowed. Turbo-compressors are, therefore, particularly advantageous as regards weight and dimensions when large volumes have to be compressed to low pressures. It must also not be overlooked that the prime movers for turbo-compressors are as a general rule, smaller, lighter and cheaper than those for reciprocating compressors.

2. *Great reliability* due to the much more simple design — no rubbing glands but only labyrinth glands, no valves and valve gear, no rubbing parts, consequently no internal lubricated parts in the air path.

3. *Air uncontaminated with oil and reduced oil consumption.*

4. *Minimum attendance and practically no upkeep expenses,* because no parts are exposed to wear.

5. *Vibrationless operation,* consequently light foundations and continuous delivery of air.

With regard to the *power consumption,* the turbo-compressor is, when under favourable conditions — i. e. large volumes and moderate pressure ratios— better or, at least, as good as a reciprocating compressor. Even when it is less advantageous as regards power consumption, preference is given to the turbo-compressor in a great many cases due to its valuable advantages.

II. UTILIZATION OF BROWN BOVERI TURBO-COMPRESSORS IN MARINE AND HARBOUR PLANTS.

1. *Scavenging turbo-blowers for two-stroke marine Diesel engines.*

The use of turbo-blowers to supply scavenging air for two-stroke Diesel engines was originally advocated by Brown Boveri in 1915—16, and the first firm to adopt this idea was Messrs. Sulzer Bros. of Winterthur (Switzerland). The initial installations were on board submarines; later on, after the war, they were also employed for merchant vessels (MS "Handicap" in 1921).[1]

The supply of air for scavenging two-cycle Diesel engines can be obtained either by positive-displacement blowers of the reciprocating or rotary type, driven off the main engines, or by independent turbo-blowers.

In addition to the general advantages already alluded to, the turbo-blower has for this application the following advantages:—

(a) Simplified layout of the main Diesel engine; the whole output becomes available for propulsion.

(b) Possibility of adjusting the volume and pressure of the scavenging air in a very economical manner to the momentary load of the Diesel engine. The resistance characteristic of a Diesel engine is

[1] For full particulars regarding the development of Brown Boveri scavenging turbo-blowers see publication 792 E "Centrifugal scavenging blowers for two cycle marine Diesel engines" as well as The Brown Boveri Review of 1927, p. 51 "New motor ships equipped with Brown Boveri turbo-blowers for scavenging and supercharging". Further particulars have also appeared in periodic articles regarding installations carried out, appearing in The Brown Boveri Review in 1925, 1928, 1929, and 1935.

purely dynamic: under these conditions varying the speed of the turbo-blowers affords the most logical and efficient method of regulation.

(c) As the turbo-blowers are independent of the main engines and require moreover very little space, they can be often installed in subsidiary compartments, which ensures a better overall utilization of the space available. It may be recalled at this juncture that quite a number of large Brown Boveri scavenging turbo-blowers are even placed athwartships, and in no single instance after many years operation have any bearing troubles occured due to gyroscopic action.

The following arguments have been advanced by the advocates of built-on reciprocating scavenging pumps: [1]

(d) The complete installation is more simple and requires less supervision, because the Diesel engine forms a single, self-contained unit (this argument applies evidently to a certain extent to single-screw cargo vessels).

(e) Smaller overall fuel consumption, because the electrical drive of the turbo-blower entails approximately 15 % energy losses in the dynamo and electric motor.

(f) Smaller electrical generating plant, and consequently slightly lower initial outlay.

With regard to point (d) it may be added that this advantage no longer applies to Diesel engines for large outputs. For these, the reciprocating scavenging pump assumes unwieldy proportions unless a subdivision over several cylinders is resorted to. At all events, driving the scavenging pump by the main motor means an additional complication — e. g. lengthening the crankshaft with additional cranks, drive by levers from the main connecting rods, or by chains from the main shaft — which is all the less desirable the greater the Diesel engine output. Furthermore, with a large Diesel engine, which is utilized to its fullest extent, quite an appreciable output is taken up for driving the scavenging pump off the main shaft which output is no longer available for propulsion. All these considerations show that, at least for Diesel engines of larger outputs, the adoption of independent turbo-blowers is fully justified, both on the grounds of design and operation.

Coming now to points (e) and (f) it may be pointed out that so far, the use of direct-current turbo-motors for electrical drives of scavenging blowers has predominated. This does not necessarily imply an appreciable increase in the size of the electrical generating plant, particularly for those installations where all auxiliaries are already driven electrically, in accordance with the most modern practice for both cargo and passenger vessels. With an electrical drive, transmission losses of approximately 15 % cannot be avoided between the auxiliary Diesel engine and the scavenging blower. In reality, however, the greater part of these losses are recuperated by the more efficient adaptation of the turbo-blower to the momentary demands for scavenging air of the main Diesel engine. In order to obviate these losses, large scavenging blowers have been driven recently by their own auxiliary Diesel engines; high-speed, four-cycle engines, with exhaust-gas turbo-charging blowers being particularly suitable for this purpose.

Under these conditions, the consumption of fuel for scavenging is, at all events, no higher than with a built-on reciprocating pump. Fig. 6 shows a scavenging turbo-blower of this description, driven by an auxiliary Diesel engine. While the blower set shown can be taken as an example that separate scavenging blower sets with auxiliary Diesel drive can be used for relatively small two-cycle Diesel engines, it should be said that such scavenging sets have been chiefly utilized, on recent years for marine Diesel engines of very big outputs. In such cases the driving power for the scavenging blower can attain 1000 H.P. and more and it is understandable that, particularly, with such big units, direct drive by an auxiliary Diesel engine is especially advantageous.

Another economical form of drive is by a steam turbine fed from a waste-heat boiler through which flows the exhaust from the Diesel engine, provided of course, that no appreciable amount of additional firing is necessary. Such steam-driven scavenging turbo-blowers have been recently used as stand-by or to supplement the built-on scavenging pumps. Fig. 7 shows a stand-by scavenging turbo-blower, driven by a steam turbine for the new Diesel-engine plant of the M. S. "Vulcania", which is equipped with two double-acting two-stroke Fiat Diesel engines, each for 13,000 H.P.

A continuous rise in the scavenging pressure has taken place during recent years. For many years the scavenging pressure remained around 1200 mm w. g., and pressures lower than 1000 mm w. g. were often sufficient; much higher values are now required, which vary from 1600 to 2400 mm w. g. for merchant vessels, and can be as high as 4500 mm w. g.

[1] See Schor:— "Spülluftgebläse oder angehängte Spülluftpumpe?", Werft, Reederei, Hafen, 1929, p. 131.

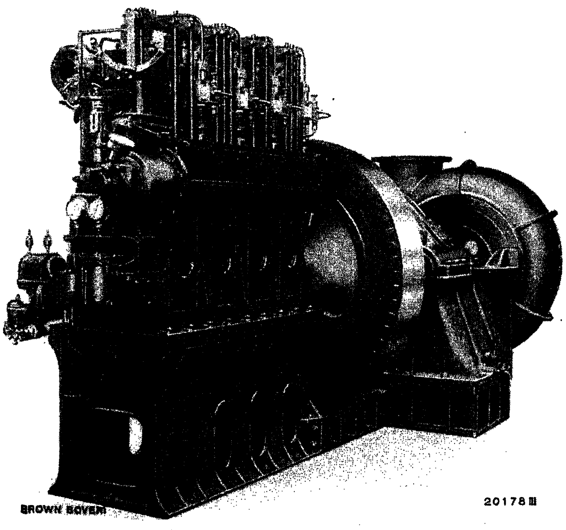


Fig. 6. — Brown Boveri scavenging turbo-blower, driven by an auxiliary Diesel engine over gearing.

The Diesel engine runs at 500 r. p. m. and the blower at 3600 r. p. m. Between both units a reduction gear is lodged. To compensate the fluctuations in torque of the driving Diesel engine the big gear wheel has an oscillation-damping spring device.

for warships. This rise may be attributed in part to the increasing use of double acting engines; furthermore, in addition to scavenging a certain amount of charging is attempted. Finally, the resistance is still further increased by waste-heat boilers, which have been employed more and more frequently of late. The pressures required can be produced by single-stage blowers, unless other considerations, such as the limitation of the speed which cannot be avoided with direct drives by electric motors render a two-stage turbo-blower compulsory.

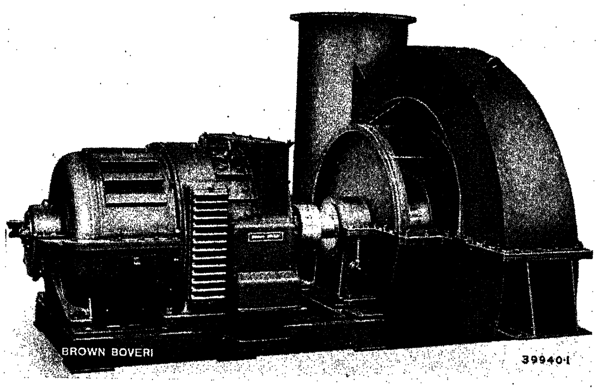


Fig. 8. — Scavenging turbo-blower set, driven by D. C. motor for the motor liner "Saturnia", which is equipped with Sulzer double-acting, two-stroke Diesel engines 2 × 13,000 B.H.P., built by the Cantieri Riuniti dell'Adriatico, Trieste.

Volume of indrawn air 1800 m³/min, delivery pressure 1800 mm w. g., 2350 r. p. m., 700 kW power input at motor terminals.

Examples of recent installations with motor-driven, scavenging turbo-blowers are afforded by the Cross-Channel motor ship "Prince Baudouin"[1] and the rebuilt liner "Saturnia", the former Diesel engines of which have been replaced by double-acting Sulzer two-stroke engines for 2 × 13 000 H.P. Scavenging air is supplied by three turbo-blowers, of which two are in operation together. Each turbo-blower handles 1800 m^3/min under 1800 mm w. g. scavenging pressure, the corresponding speed being 2350 r. p. m. The power input at the motor terminals then amounts to 700 kW (220 V, 3180 A), the D. C. turbo-motors being the largest that have ever been built. Another notable feature is that these scavenging blower sets are placed athwart-ship. This large amount of scavenging air is drawn directly through the complete engine room to ensure thorough ventilation and cooling of same.

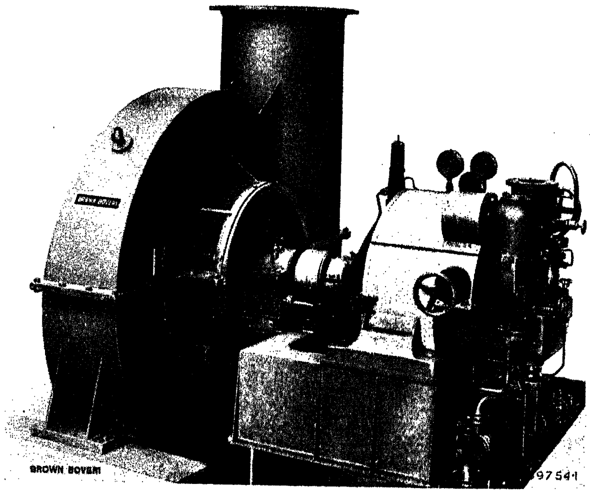


Fig. 7. — Scavenging turbo-blower set with steam turbine drive (steam from waste-heat boilers), for the motor liner "Vulcania", which is equipped with Fiat double-acting, two-stroke Diesel engines, 2 × 13,000 B.H.P.

Volume of indrawn air 1200 m³/min, delivery pressure 2600 mm w. g., 4400 r. p. m., 620 kW power input.

Up to the end of 1935, 265 Brown Boveri scavenging turbo-blowers, with an aggregate volume of indrawn air of 186,700 m^3/min have been supplied. Taking a mean demand of 0·14 m^3/min of scavenging air per B.H.P., it will be seen that the total Diesel output of 1·33 million B.H.P. is scavenged by Brown Boveri turbo-blowers. The mean volume per turbo-blower is 700 m^3/min to which corresponds 5000 B.H.P. Diesel engine output.

[1] A detailed description of the scavenging turbo-plant for this ship appeared in the Brown Boveri Review No. 4, 1935, p. 96.

2. *Exhaust-gas turbine-driven charging turbo-blowers for raising the output of marine Diesel engines.*

Charging four-cycle Diesel engines represents a more recent application for turbo-blowers than scavenging. Its development has been greatly furthered by the researches of Mr. Alfred Büchi, dipl. engineer, in Winterthur and by Brown Boveri. At the present time, there are practically no four-cycle engines which do not utilize some form of charging or after charging. Charging according to the Büchi system possesses the following advantages over methods which have been subsequently evolved:—

(a) Greater efficiency because the energy necessary for driving the blower is obtained from the exhaust gases, the useful heat of which can be still further recuperated after the turbine in waste heat boilers.

(b) The design of the Diesel engine requires no modification whatsoever, because the blower set runs as an independent unit, and may be said to form part of the exhaust mains. For this reason, charging according to the Büchi system can be very easily added to existing Diesel engines.

In a comparative study[1] based on first-hand experience on a large number of existing machines charged according to various systems, Dr. Pflaum, chief engineer of the MAN Augsburg Works, comes to the following conclusions:—

(a) Exhaust gas turbo-charging according to the Büchi system gives the best results with regard to fuel consumption, this advantage being the more pronounced the more the output is raised.

(b) By subdividing the exhaust mains in accordance with the Büchi process, an efficacious scavenging of the combustion space can be obtained, whilst the back-pressure conditions for the Diesel engine are so favourable that they cannot be surpassed by any other charging process.

(c) It is only when the power increase reaches 70 % that the same amount of heat is taken off in the cooling water of a Diesel engine charged according to the Büchi system as with an ordinary uncharged engine. This is due to the large amount of air for scavenging and to the greater amount of excess air at which these machines operate.

(d) It is invariably noticed that charged Diesel engines run more smoothly to the ear.

[1] Werft, Reederei, Hafen, Vol. 12, June 15, 1935 "Auflade-Dieselmaschinen u. Schiffantrieb" by Dr. Pflaum.

(e) Graphical research confirms that the bearing loads and torque diagram become more uniform with charging.

(f) Exhaust-gas charging enables the output to be increased with the smallest expenditure of weight. With a favourable arrangement of the charging set, practically no additional floor space is required.

It is, therefore, hardly surprising that leading Diesel engine builders all over the world are now employing exhaust gas turbo-charging according to the Büchi system, and that its use is becoming more and more widespread.

Recently, notable developments with Büchi charging have been taking place[1] which have enabled its use to be extended to small, high-speed Diesel engines. Until quite a short time ago an output as large as 400 B.H.P. was considered to represent the lowest limit for exhaust gas turbo-charging. Thanks to increased efficiencies of the turbo-blowers and exhaust-gas turbines, this limit has been now brought down to about 200 B.H.P., and an experimental plant for 100 B.H.P. is now under construction. Consequently exhaust-gas charging can be now applied not only to main propulsion engines, but also to the small auxiliary engines which are now used on board all ships for driving dynamos.

Single-stage turbo-blowers are employed for pressure ratios up to about 1·45, mean effective pressures around 10 kg/cm^2 being then obtainable. For greater pressure ratios, as come into consideration at high

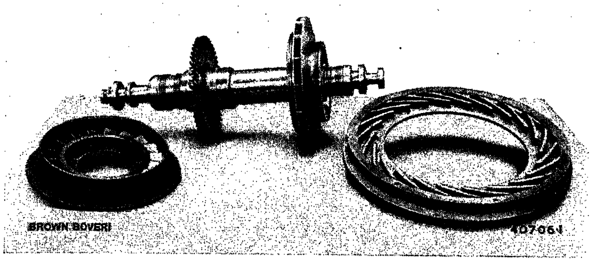


Fig. 9. — Parts of a Brown Boveri exhaust-gas charging turbo-blower.
Blower impeller. Turbine disc.
Diffuser. Turbine nozzle ring.

altitudes, two-stage turbo-blowers are necessary. Fig. 9 shows the moving and guiding parts of a charging turbo-blower set driven by exhaust-gas turbine, while Fig. 10 gives an idea of how the exhaust-gas turbo-set forms one with the Diesel engine, both as regards design and operation. Up to the end of 1935, Brown Boveri has supplied altogether 220 charging turbo-

[1] The Brown Boveri Review, 1935, No. 1/2, pp. 56—57; also year 1936, No. 1/2, pp. 17—18.

blower sets for an aggregate Diesel-engine output of 480,000 B.H.P; these figures including 128 sets for marine plants. These installations comprise the large liner "Reina del Pacifico" with a total engine output of

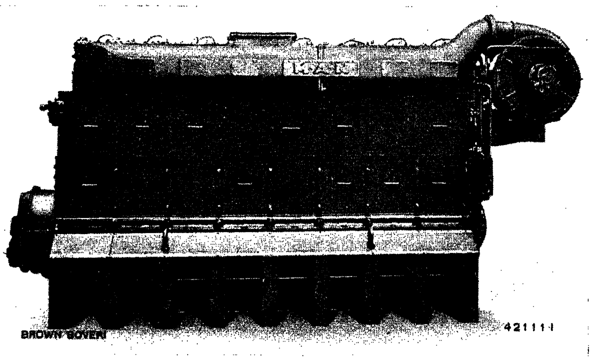


Fig. 10. — M. A. N. four-stroke marine Diesel engine with built-on Brown Boveri exhaust-gas charging turbo-blower for increasing the output according to the Büchi system. Continuous output 1400 H.P., 700 r. p. m., mean effective pressure 8·4 kg/cm².

22,000 B.H.P., as well as a large number of cargo and passenger ships, and of late an increasing number of submarines as well as other light ships for navies.

Now that charging four-cycle engines has become recognized practice, the charging of two-cycle engines is being tackled. Considerable possibilities are offered if the output of existing two-cycle marine Diesel engines can be raised, and in this connection, the most promising way to approach the problem appears to be according to the Brown Boveri-Curtis arrangement (Fig. 11), which consists of connecting a charging turbo-blower driven by an exhaust gas turbine in series with the existing scavenging blowers — which can be either built on pumps or electrically-driven turbo-blowers. In other words, the charging turbo-blower may be said to boost the existing scavenging blower.

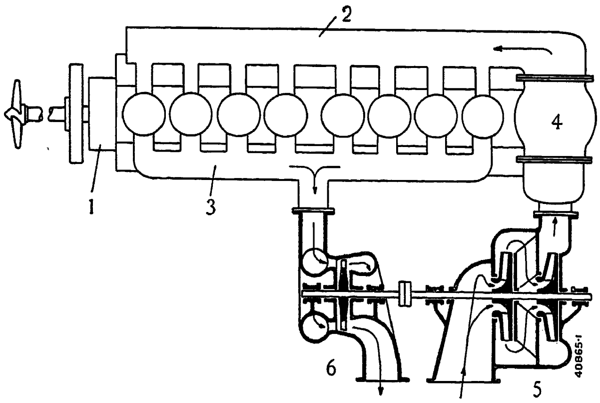


Fig. 11. — Diagram showing method of charging two-stroke marine Diesel engines according to the Brown Boveri-Curtis system.

The charging turbo-blower (5) is driven by an exhaust-gas turbine (6) and connected in series with the existing reciprocating scavenging pump (4), i. e. the scavenging pump is charged; (2) is the scavenging-air pipe, and (3) the exhaust-gas pipe.

3. *Turbo-blowers for marine boiler plants.*

The earliest application of turbo-compressors on board ship was for inducing combustion air, i. e. producing forced draught, because relatively large volumes of air have to be handled under low pressures, conditions for which reciprocating blowers are not suitable. The pressures coming into consideration, here, vary between approximately 40 mm w. g. for merchant vessels with Howden's system up to 300 mm w. g. for warships with closed stokeholds and oil firing. With Velox steam-generator plants on board warships, pressures up to 25,000 mm w. g. are actually reached. For the conditions first mentioned, even the centrifugal blower does not represent the most favourable solution, because with such small pressures it must run at low speeds if good efficiencies are to be obtained, with the result that its dimensions as well as those of its drive are liable to become unwieldy. In such cases *axial blowers* are more suitable. Fig. 12 shows the design of a single-stage vertical-shaft axial blower, driven by a steam turbine, for a warship boiler plant. Axial blowers are a new development and are derived from the aerodynamical theories developed in connection with airoplane wings. They are, therefore, typical flow machines, the air going through the blower axially. With single stage designs, the impeller has only a few vanes resembling propellers. Compression is produced by the impulse given to the air by the vanes, which impart an axial acceleration and a twist. The kinetic energy is then converted into

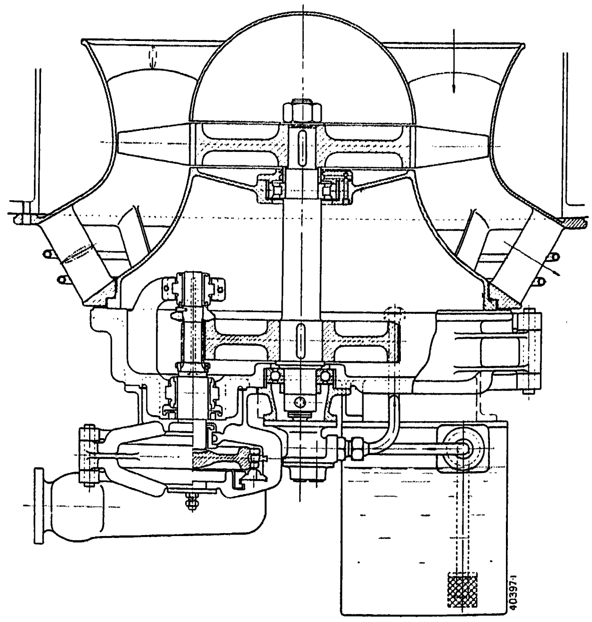


Fig. 12. — Brown Boveri single-stage, vertical-shaft axial blower, with steam turbine drive for warship boiler plant with closed stokehold.

pressure in the diffuser casing following the impeller. If, according to Keller[1], the term of speed coefficient for single stage axial blowers is defined as

$$\sigma = 2 \cdot 105 \cdot Q^{\frac{1}{2}} \left(\frac{\Delta p}{\varrho}\right)^{-\frac{3}{4}} \cdot n$$

where

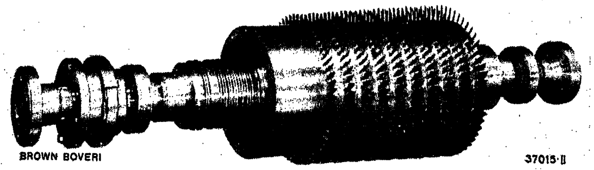
Q is the volume handled in m^3/s.

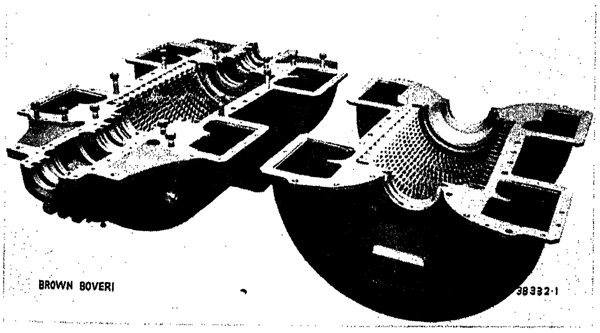
Δp is the static pressure rise in the blower in kg/m^2.

ϱ is the gas density in $kg \cdot s^2 \cdot m^{-4}$.

n = number of revolutions per second.

Then the speed coefficient for ordinary centrifugal fans amounts to 0·2—0·5, whereas for axial blowers the corresponding figures are 0·5—4. It will be seen, therefore, that the latter may be immediately classed as high-speed machines. They are consequently smaller and lighter than centrifugal compressors and can be frequently coupled directly to high-speed drives. The pressure-volume curve of axial compressors is steeper than that of centrifugal compressors and the pumping limit is somewhat less favourable, i. e. closer to the operating point having best efficiency, which incidentally can amount to 80 % and more notwithstanding the high speed coefficient. Due to their characteristics, axial blowers are only suitable for applications where the resistance of the system is purely dynamical (delivery against an invariable aperture), as is precisely the case in marine boiler plants.





Figs. 13a and 13b. — Rotor and casing of a Brown Boveri multi-stage axial compressor.

The compressor is for charging a Velox steam generator, and is driven by a gas turbine.

Figs. 13a and 13b show the rotor and casing of a multi-stage axial compressor as used for Velox steam generators, which, it may be recalled, are fired under pressures of 2·5—3·5 kg/cm², and have been already adopted in a number of instances for ships. Externally, an axial compressor bears a close resemblance to a reaction turbine, except that the flow takes place in opposite directions. Parsons attempted to build multi-stage axial blowers as long ago as 1903. It was, however, only on the basis of recent aerodynamical research that suitable blade profiles could be evolved. Brown Boveri can undoubtedly claim the distinction of having been the first to construct a serviceable axial compressor.

4. *The turbo-compressor as a steam compressor and heat pump on board ship.*

Yet another application of the turbo-compressor on board ship is afforded by heat pumps in evaporating and refrigerating plants. According to the second law of thermodynamics, heat cannot flow without expenditure of energy from a lower to a higher temperature state. Consequently if heat (energy) is available under a low temperature, it can only be utilized if energy is expended to pump it to a higher temperature state — hence the term heat pump — and it is then allowed to give up work by an energy drop to the ambient conditions.

With an evaporator as shown in Fig. 14, the heat pump enables the steam given off to be utilized for heating the solution, in that its latent heat is pumped to a higher temperature level, and is thus employed usefully instead of being thrown away in a condenser. In this manner, evaporation can take place without drawing to any appreciable extent on an external source of heat. If there were no heat losses ($Q_v = 0$) and if the heat exchanging surfaces of the evaporator were infinitely great (te = ta), it would be possible to keep the evaporator going without any addition of heat, once started up. However, as such conditions cannot be realized in practice, heat has to be added from an external source:— in the present case it is in the equivalent form of mechanical energy expended to drive the heat pump which serves to create the temperature difference necessary for heating, i. e. $Qv + Qa = AL$. The use of heat pumps in evaporator plants is recommended only if no possibility exists for utilizing in another manner the latent heat of the steam given off.

[1] Keller „Axialgebläse vom Standpunkt der Tragflügeltheorie". Communication by the Aerodynamical Institute of the Swiss Federal Institute of Technology, Zurich 1934.

Such possibilities are almost always available on board ships with steam plants, where the steam given off can be employed for heating feed water. Consequently there is no justification for a heat pump in such cases. On the other hand, it is conceivable that for large motor liners which require considerable quantities of fresh water, evaporators with heat pumps can represent quite an attractive proposition. As can be seen diagrammatically in Fig. 14, an installation of this description would be exceedingly simple. It would consist essentially of the evaporator proper, with preheater and turbo-compressor for steam, which has been assumed electrically driven and fed from a Diesel generating set on board. An evaporator of this

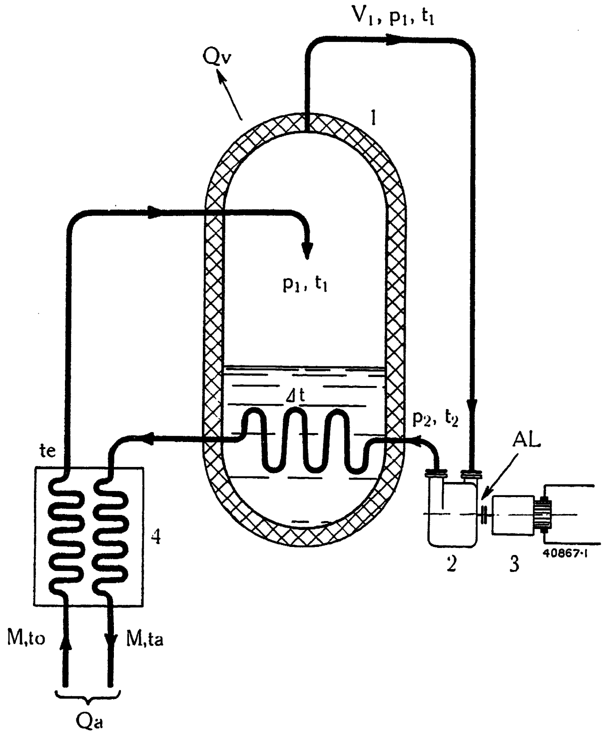


Fig. 14. — Diagram of a feed-water evaporator with heat pump.

1. Evaporator.
2. Turbo compressor for steam.
3. Driving motor.
4. Preheater for make-up water.

Q_a. Heat losses due to imperfect heat exchange.
O_v. Heat losses due to radiation and leakage.
AL. Heat addition by work of compression.

Example: Evaporator output: M = 80 tons per day = 3330 kg/h.

t_o. 20° C
t_e. 90° C
t_1. 101·7° C
t_2. 112·7° C
p_1. 1·1 kg/cm² abs
p_2. 1·6 kg/cm² abs $\Big\}\ \frac{p_2}{p_1} = 1{\cdot}46$

Heat drop: t = 11° C
t_a 40° C.
Q_a. 66,600 kcal/h.
A_L. 82,000 kcal/h.
V_1. 86·5 m³/min.
L. 95·5 kW.

Three-stage blower, approximately 12,000 r. p. m.

Fuel-heat consumption for evaporating 1 kg of make-up water:

$$\frac{95{\cdot}5 \times 860}{3330 \times \eta_d \times \eta_{el}} = \underline{83 \text{ kcal/kg.}}$$

of which approximately 25 kcal/kg are available for the evaporator, whereas the remainder is lost in the Diesel engine and electric transmission.
η_d. 0·37 % = Diesel-engine efficiency.
η_{el}. 0·81 % = Electrical-transmission efficiency between Diesel engine and steam compressor.

description would be operated preferably under pressures exceeding that of the atmosphere in order to eliminate difficulties due to air leaking in. The temperature difference in the evaporator between the heating steam — i. e. the steam given off after compression — and the sea water which has to be evaporated would have to amount to at least 10° C. However, the heat pump and particularly its motor should be so liberally dimensioned that they are capable of producing, if necessary, a greater temperature difference, so as to be able to cope with all contingencies (dirty heat exchanging surfaces, raised boiling temperatures with increased concentration, steam losses due to gland leakage and radiation). For the sea water to be evaporated, the warm water leaving the jackets of the Diesel-engine cylinders can be used to advantage. It is first of all preheated in a heat exchanger by the condensate from the evaporator. Fig. 14 contains figures based on conditions with an evaporator for 80 tons per day. The efficiency of this process must be obviously examined for each individual case.

Another form of heat pump is afforded by the *refrigerating machine.* In this case, heat is removed under a low temperature, and its state is raised until its temperature is higher than that of the cooling water, which carries its heat away. Up to the present, reciprocating compressors have been used as heat pumps in such cases, and ammonia (NH_3) or carbon dioxide (CO_2) as refrigerants. Without a doubt, for larger capacities exceeding 75,000 kcal/h or 25 tons ice capacity, turbo-compressors will prove in the future a serious competitor to reciprocating compressors, on account of the considerable advantages as regards space and operation afforded by the former. Fig. 15 gives an idea of the appearance of such a refrigerating plant: the turbo-compressor with its drive, together with the evaporator and condenser are united together to form a single closed unit, without any glands, which has been called Frigibloc, and which requires about one third of the space taken up by an ordinary refrigerating plant. The oil-free delivery of the refrigerant vapour by the turbo-compressor is of importance, because an oil film on the heat exchanging surfaces has a harmful influence on the heat transfer. The gas-tight casing prevents all loss of refrigerant. The refrigerants used are those haloid hydrocarbons, the vapours of which have a sufficiently large specific volume and a moderate pressure ratio — i. e. conditions which are favourable for turbo-compressors. The most suitable

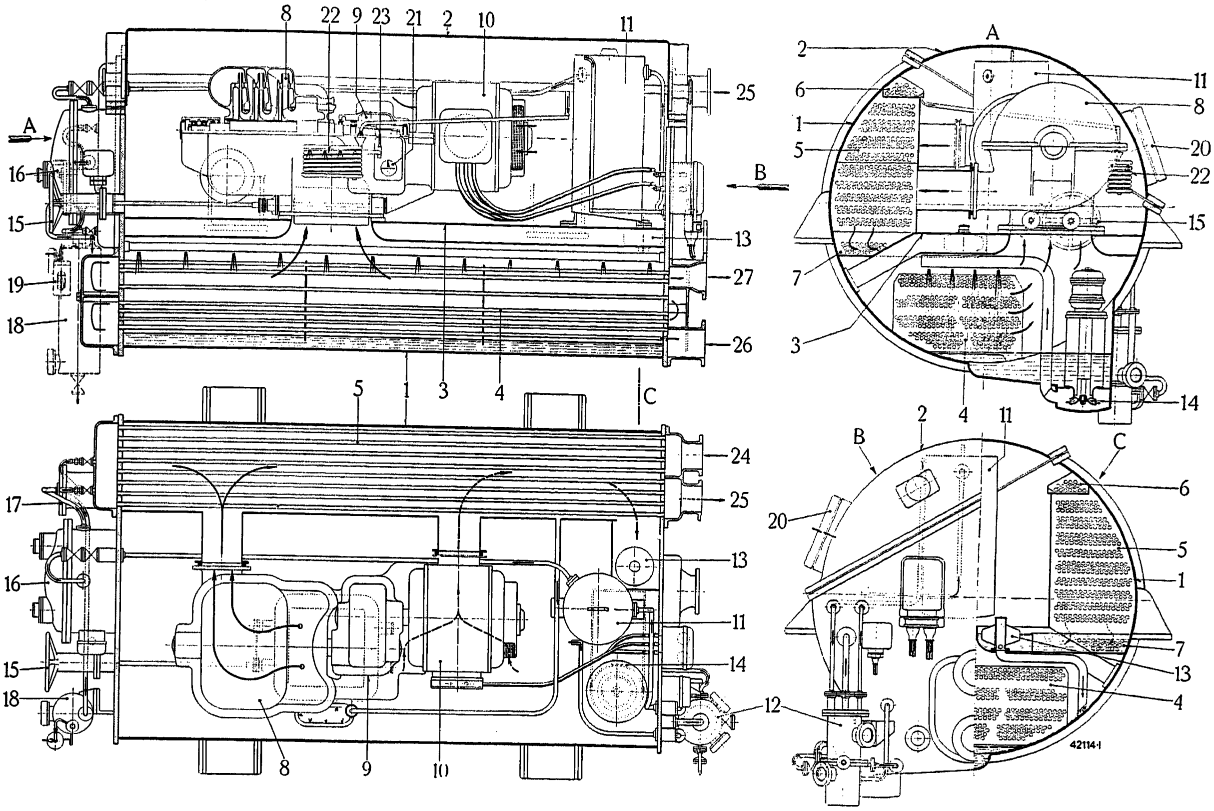


Fig. 15. — Brown Boveri Frigibloc as marine refrigerating unit.

1. Casing.
2. Cover.
3. Floor.
4. Evaporator.
5. Condenser.
6. Auxiliary condenser.
7. Undercooler.
8. Turbo-compressor.
9. Gearing.
10. Motor.
11. Air collector.
12. Water and air separator.
13. Float valve.
14. Circulating pump.
15. Drive of compressor suction throttle valve.
16. Vacuum pump.
17. Air after-cooler.
18. Container for 17.
19. Inspection glass.
20. Porthole.
21. Oil level.
22. Oil cooler.
23. Oil thermometer.
24. Cooling-water inlet.
25. Cooling-water outlet.
26. Brine inlet.
27. Brine outlet.

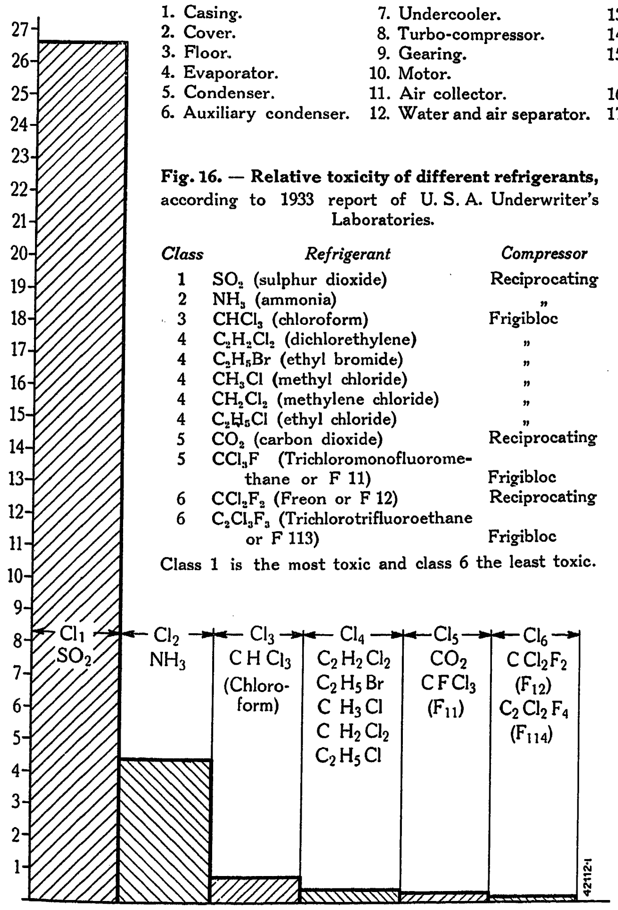


Fig. 16. — Relative toxicity of different refrigerants, according to 1933 report of U. S. A. Underwriter's Laboratories.

Class	*Refrigerant*	*Compressor*
1	SO_2 (sulphur dioxide)	Reciprocating
2	NH_3 (ammonia)	"
3	$CHCl_3$ (chloroform)	Frigibloc
4	$C_2H_2Cl_2$ (dichlorethylene)	"
4	C_2H_5Br (ethyl bromide)	"
4	CH_3Cl (methyl chloride)	"
4	CH_2Cl_2 (methylene chloride)	"
4	C_2H_5Cl (ethyl chloride)	"
5	CO_2 (carbon dioxide)	Reciprocating
5	CCl_3F (Trichloromonofluoromethane or F 11)	Frigibloc
6	CCl_2F_2 (Freon or F 12)	Reciprocating
6	$C_2Cl_3F_3$ (Trichlorotrifluoroethane or F 113)	Frigibloc

Class 1 is the most toxic and class 6 the least toxic.

refrigerants for use in Frigiblocs are methylene chloride (CH_2Cl_2), ethyl chloride (C_2H_5Cl), ethylene chloride ($C_2H_2Cl_2$), ethyl bromide (C_2H_5Br), as well as of a number of similar fluorine compounds, etc. Fig. 16 shows the relative degree of toxicity of various refrigerants, chloroform having been also included for comparison purposes. As will be seen, the new refrigerants as used in the Frigibloc, are less harmful than those commonly employed formerly. No refrigerant known is absolutely harmless (except water vapour), and it should, therefore, be the duty of every designer to strive to ensure that no leakage of refrigerant can occur. Whenever possible, refrigerants are adopted for Frigiblocs which have pressures lower than that of the atmosphere in the whole operating cycle. Consequently no gas can escape outwards, at the worst only air can penetrate in, and this can be effectively prevented by the simple hermetic seal adopted for the flanges of the casing. The new refrigerants are quite neutral as regards their chemical action on the materials employed, this applying in particular to motor insul-

ating materials. Consequently the motors for driving the turbo-compressor as well as for auxiliary purposes can be all enclosed inside the Frigibloc, and be cooled with refrigerant vapours. On account of their simple and robust design, squirrel-cage induction motors are best suited for this purpose. In this manner all glands for moving parts can be done away with and the only external openings of the Frigibloc are for electric cable leads, and, in addition to these, the only external connections to the Frigibloc are for water and brine. It may be objected that up to the present, direct-current is employed almost exclusively for ships auxiliary drives. It may be safely asserted, however, that the advent of alternating current is only a question of time; in the meanwhile either a converter set must be resorted to, or, if a direct-current drive is adopted, the main motor must be located outside the Frigibloc, in a similar manner to that employed for steam turbines, and use be made of a gland. As the latter has to tighten only a supported shaft of small diameter, which is only subjected to torsional stresses, a reliable and simple design can be adopted. Finally, it may be mentioned that the Frigibloc forms a complete unit, which can be tested before leaving the works, and is erected as such on board ship. The power consumption of a Frigibloc for outputs exceeding 200,000 kcal/h is equal to or better than that of plants with reciprocating compressors, whereas for smaller outputs it is, on the other hand, slightly higher, which, however, is of no very great importance, as the magnitude of the excess should be around 5 kW for the smallest units, and 15 kW for the larger units under the most unfavourable conditions.

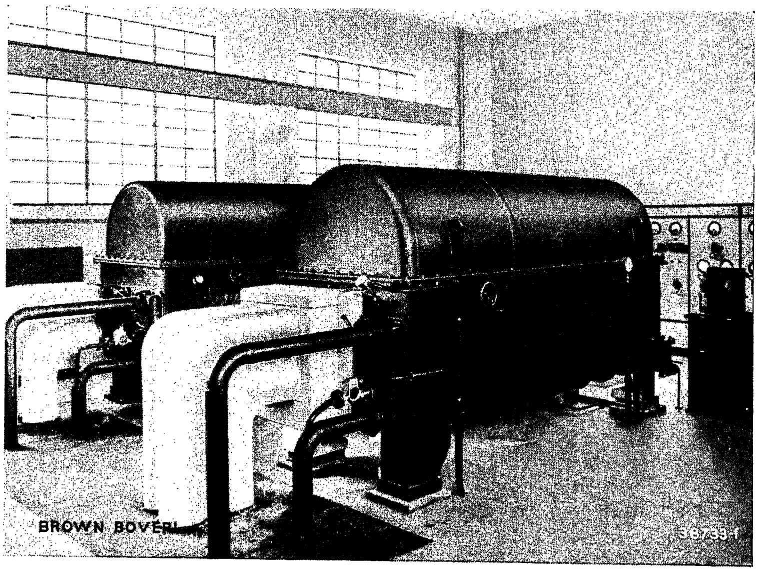


Fig. 17. — Two Frigiblocs each for 300,000 kcal/h for a slaughter house and fish freezing plant in Helsingfors harbour.

Each Frigibloc has two evaporators of which one supplies brine at — 15·5° C (60,000 kcal/h) and the other at —8° C (240,000 kcal/h.)

Fig. 17 shows an installation with two Frigiblocs for the slaughter house in Helsingfors harbour. The Frigiblocs run quite automatically, just like a household refrigerator. Besides the saving in weight and space already alluded to, as well as automatic operation, the Frigibloc is characterized in comparison with reciprocating machines by its silent and absolutely smooth running. It is also possible to subdivide a Frigibloc internally so that several evaporator temperatures can be obtained simultaneously, which is an advantage when there are a number of refrigerated rooms in which different temperatures are required. The two Frigiblocs in Helsingfors, for example, are designed in this manner; each has a double evaporator, of which one cools brine to —15·5° C and the other to —8° C.

In the United States, water vapour refrigerating machines have been recently revived. Water serves here as refrigerant, but such installations are only suitable for air-conditioning plants, due to water freezing when the temperature becomes lower than 0° C. However, air-conditioning plants will become in the future a necessity for ships which operate in the tropics. The difficulties which have to be overcome with water vapour as a refrigerant may be ascribed to the very low saturation pressures (about 0·02 kg/cm^2) at low temperatures, which occur concomitantly with very large specific volumes. Consequently, the turbo-compressors will have also very large dimensions, and will be accordingly expensive. The maintenance of very high vacua gives rise to very great difficulties, which must necessarily limit the scope of water-vapour refrigerating machines.

For conditioning plants, for dehumidifying and cooling air, the *Brown Boveri air expansion refrigerating machine*[1] should prove in certain cases attractive, as it requires no refrigerant whatsoever, the air itself undergoing the required temperature variations. Although the power input of such installations is higher

[1] Brown Boveri Review, 1930, volume 9, page 271, Ad. Baumann: "Cooling and drying air (air conditioning) with particular reference to the air expansion process".

than that of vapour-compression machines, they have over the latter the undisputed advantage of simplicity and absolute harmlessness. The process as such has been already used for years on board submarines. It

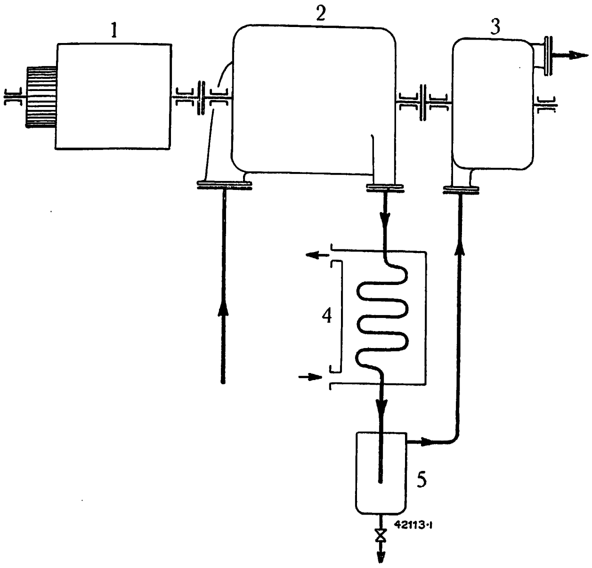


Fig. 18. — Diagram showing the operating principles of an air-conditioning (drying and cooling) plant according to the air-expansion process.

1. Driving motor. 3. Expansion turbine. 5. Water separator.
2. Turbo-compressor. 4. Air-cooler.

operates in principle in the following manner (Fig. 18): — the air to be treated is compressed first of all by a turbo-blower, then cooled by ordinary water in a surface cooler, and finally expanded in a turbine where the air gives up useful energy and is cooled at the same time to a temperature lower than that of the surrounding atmosphere. At the same time, the humidity in the air is precipitated as water (tests carried out on such an installation gave a water precipitation of 95 % of that theoretically possible).

For the sake of completeness, mention must be also made of the use of turbo-compressors on board ship for compressing steam, as adopted for instance for the Götaverken system for improving the efficiency of reciprocating steam engines. As with the Brown Boveri exhaust turbine system, the purpose of this arrangement is to make use in a turbine of the energy of exhaust steam from a reciprocating engine which would be otherwise lost due to incomplete expansion. With the Brown Boveri system, the mechanical energy recuperated is transmitted directly to the propeller shaft, whereas with the Götaverken system, the exhaust-steam turbine drives a steam compressor, and the recuperated energy is returned to the steam in the form of heat of compression[1]. Practically, this is carried out in such a manner, that the steam leaving the high-pressure cylinder is compressed before it enters the middle-pressure cylinder, and at the same time superheated by the work of compression. A condition sine qua non for the efficiency of this system, which is inherently lower than that of the Brown Boveri exhaust-steam turbine system owing to the numerous energy transformations, is that the steam to be compressed must be absolutely dry when it penetrates into the compressor, because otherwise if water is present, part of the energy recuperated is thrown away in the latent heat absorbed to re-evaporate water. A steam turbo-compressor with exhaust-steam turbine, as used for the Götaverken system, has great similarity with a Büchi charging turbo-blower with exhaust-gas turbine drive, even as far as the assembly with the steam turbine is concerned, so that one is tempted to speak of "exhaust-steam turbo-charging of reciprocating steam engines."

5. *The turbo-compressor as tank blower in submarines and in plants with activated stabilizing tanks.*

Fig. 19 shows a recent design of a diving-tank blower for submarines[2]. The design is interesting in so far that these blowers furnish an example of the

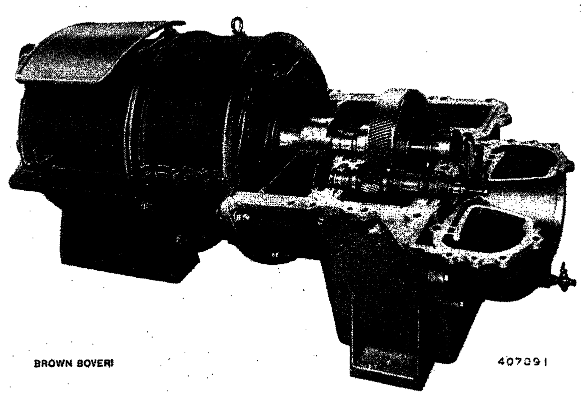


Fig. 19. — Brown Boveri submarine diving tank turbo-blower.

Volume of indrawn air 30 m³/min.
Pressure ratio 1·8.
Speed 33,000 r. p. m. (peripheral speed 345 m/s).
Drive by D. C. turbo-motor for 5500 r. p. m. over gearing.

[1] The basic idea to connect a steam turbine after a reciprocating engine plant, and to couple the former with a steam compressor which takes steam from a place in the system ahead of the turbine and then returns it to the system after compression appears to have been originally propounded by B. Graemiger, Zürich (DRP 313842 of 22. IX. 1917).

[2] The purpose and method of operation of these blowers has been described in detail in The Brown Boveri Review, 1929, No. 12, p. 319 "Brown Boveri turbo-blowers on submarines".

extreme saving of weight and bulk obtainable. These blowers have to run for about only five minutes when the submarine emerges:— during the remainder of the time they remain idle. The smallest weight possible and extreme reduction in space taken up are consequently conditions which the designer of these blowers is compelled to meet. The turbo-blower shown is built to deliver 30 m^3/min of air under a pressure of 1·8 kg/cm^2 absolute: it runs at 33,000 r. p. m. to which corresponds a peripheral speed of approximately 350 m/s for the impeller. It will be noticed that the pressure is produced by only a single impeller, which is provided with open radial blades. For these high speeds, this impeller design must be necessarily adopted. Their efficiency is unfortunately somewhat lower than that of standard impellers with blades bent backwards, but in the present case the efficiency is a secondary consideration. The turbo-blower is driven by a direct-current turbo-motor running at 5500 r.p.m., over gearing. The turbo-blower almost vanishes when its size is compared to that of the gearing and motor. It is evident that extensive use is made of light-metal alloys for such blower sets. Quite a large number of these turbo-blowers have been supplied.

A similar application to that just examined is afforded by *stabilizing-tank blowers*, which are required in connection with the activated stabilizing tanks which have been introduced of late. As known, they serve to dampen the rolling motion of a ship. Whereas formerly the water level in these tanks was converted by natural means by the movement of the ship into oscillations, the movement of the masses of water has been more recently forcibly controlled. Compressed air is used for this purpose, which is produced by centrifugal blowers. The blower operates in such a manner that it is loaded and unloaded by rotary valves, located in the suction and delivery mains between the blower and stabilizing tanks. The movement of the masses of water in the tanks is controlled by alternatively drawing in air from one of them and raising the pressure in the other. Existing systems comprise those of Frahm (Blohm and Voss), SSW and Flamm, the first two having been already been installed and operated on board ships. The turbo-blowers used for these purpose are of single-stage design, electrically driven, and are similar to scavenging blowers also with respect to pressure and volume conditions.

6. *Turbo-blowers for pneumatic conveying plants.*

In conclusion, a brief description may be given of turbo-blowers for pneumatic conveyors[1]. In this case, the blower operates as an exhauster, and evacuates air so as to obtain suction pressures of 0·4 to 0·5 kg/cm^2 abs, and thus produce a draught having velocities of 20—40 m/s, which carries along the granular material to be conveyed — e. g. grain, small pieces of coal, etc. The amount thus transported weighs approximately 10 to 15 times the weight of air exhausted. Reciprocating and Roots blowers are extensively used for this purpose, but in recent years turbo-blowers have found increasing favour. The Swiss firm of Bühler Brothers in Uzwil has to be credited with extensive pioneering work in this connection. Turbo-blowers are suitable for conveyor capacities exceeding 30 tons per hour. The property of the turbo-blower to ensure continuous delivery is particularly valuable here. In addition, the small space required and smooth

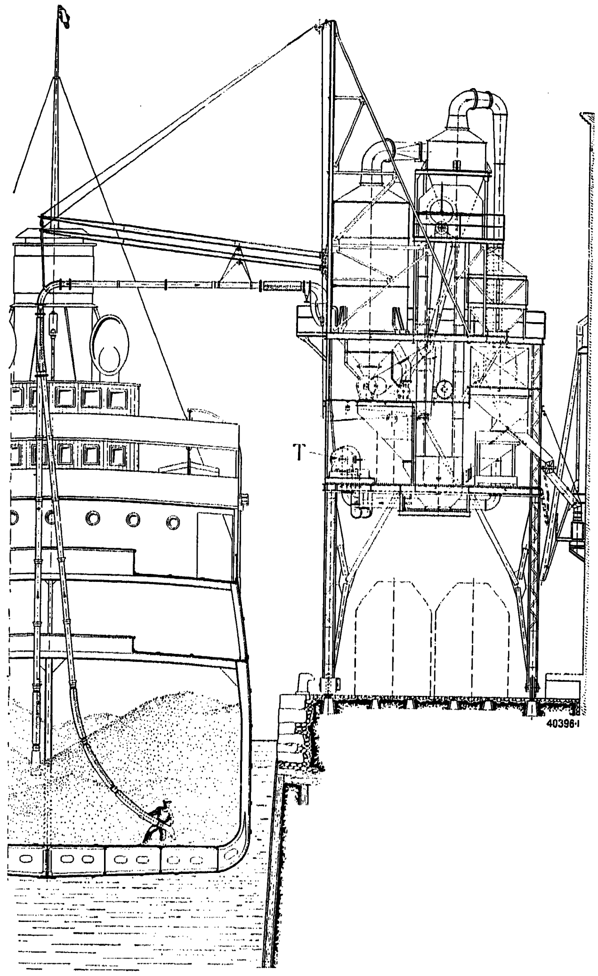


Fig. 20. — Arrangement of a mobile, pneumatic grain-conveying plant in the free port of Copenhagen for 220 tons per hour, by Bühler Brothers, Uzwil (Switzerland).

The air is exhausted by a Brown Boveri three-stage turbo-blower.

[1] Full details appeared in The Brown Boveri Review, 1926, No. 12, p. 289.

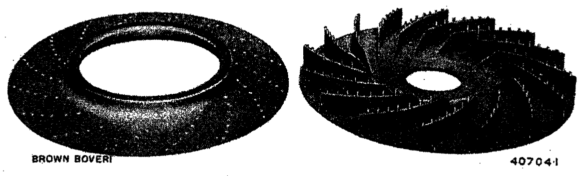


Fig. 21. — Impeller for a Brown Boveri turbo-compressor.
The rivets uniting the blades to the hub and covering discs are milled solid out of the blading material. There are consequently no rivets in the air passages exposed to erosion and corrosion. The air passages are perfectly smooth with no projecting rivet heads. The covering disc with inlet ring and the hub and hub disc are forged in one piece for highly-stressed impellers.

running are also precious properties. This accounts for the preference given to turbo-blowers for movable plants, as they can be mounted on same, whereas the large reciprocating pumps have to be installed as a general rule in a separate stationary machine house, which necessitates disconnecting the air piping whenever the conveyor moves away. Fig. 20 shows a recent installation having a capacity of 220 tons per hour installed by Messrs. Bühler in the free port of Copenhagen, use being made of a Brown Boveri turbo-blower. For reliable operation, no matter whether a reciprocating or turbo-blower comes into consideration, it is essential that adequate means should be taken to ensure dust precipitation before the blower, in order to avoid undue wear. For this purpose means are taken to ensure dust precipitation in the grain separator, and in addition, a cyclone for separating out the dust is fitted before the blower. It is very important to adopt impellers of substantial design, as shown for instance in Fig. 21. Alloy steel is used throughout and the rivets, machined solid out of the blades, bind these to the hub and coverning discs. No rivet heads are, therefore, exposed to erosion in the impeller passages, which are smooth and free from any obstructions.

(MS 944) *E. Klingelfuss. (D.M.)*

BROWN BOVERI A.C.-D.C. MUTATORS IN THE SERVICE OF THE CONSOLIDATED MINING & SMELTING COMPANY OF CANADA, LTD.

Decimal index 621. 314. 652. 2 : 621. 357.

THE Consolidated Mining & Smelting Company of Canada, Ltd. is one of the largest mining concerns and the largest producer of electrolytic zinc and lead in Canada. In 1928 the demand for zinc was such that the existing rotary converter equipment of the Company was being used to full capacity for the electrolytic production of zinc and cadmium. It, therefore, became necessary to install additional conversion equipment so as to be in a position to meet the increasing demands of the zinc market. An order was accordingly placed with Brown, Boveri & Co., Ltd., in December 1928 for mutator equipment. Three 10,000-A double mutator units, each of 5600 kW at 560 V, were installed giving a total D.C. output of 16,800 kW.

A description of this plant will be found in The Brown Boveri Review of October 1930, but it may be of interest here to recapitulate, briefly, the reasons which spoke in favour of the application of mutators as opposed to rotary converters:—

Small floor space.
Imperviousness to acid-laden gases and fumes.
Absence of commutators, slip-rings and windings requiring periodic cleaning.
Noiselessness.
Insensitivity to voltage fluctuations and frequency variations in the 60-kV primary supply line.
Absence of heavy foundations.

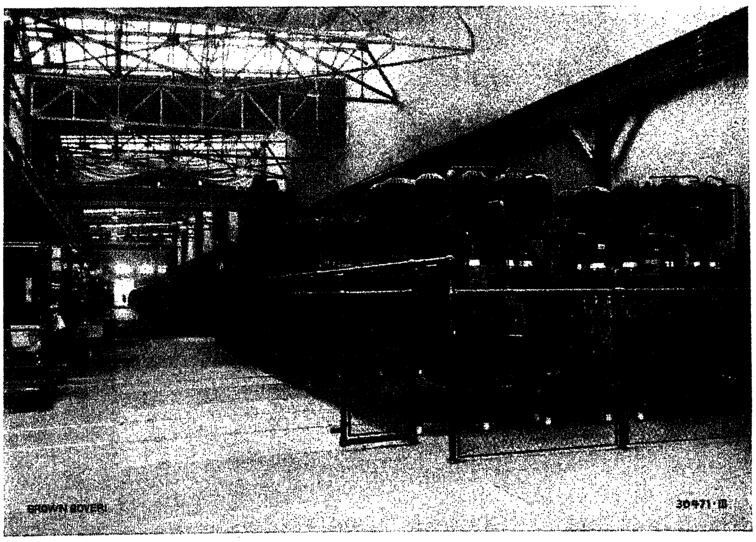


Fig. 1. — Zinc-plant substation.
In foreground, three double mutator units each for 5600 kW and, in background, ten rotaries each for 2500 kW.

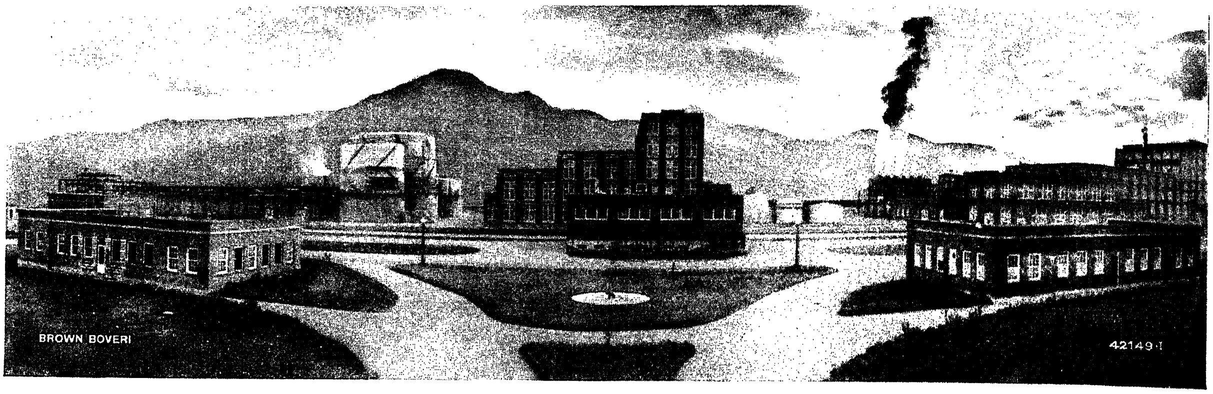


Fig. 2. — Consolidated Mining & Smelting Co. of Canada, Ltd. Warfield fertiliser plant.

A general view of the machine room of this plant is shown in Fig. 1.

In 1929, the Consolidated Mining & Smelting Company decided to undertake the manufacture of artificial fertiliser and proceded to build for this purpose its imposing Warfield plant, shown in Fig. 2. This plant is situated in the Rocky Mountains of Canada at an altitude of about 2200 ft. above sea level and is some two miles distant from the zinc and smelting plant previously referred to in this article.

The artificial fertilisers produced by the Consolidated Mining & Smelting Company are ammonium sulphate, ammonium phosphate and triple superphosphate. The ammonia required for this purpose is obtained by the combination of nitrogen and hydrogen, in the presence of a catalyst, the nitrogen being produced by the liquefaction of air and the hydrogen by the electrolytic decomposition of water in cells. The sulphuric acid is obtained from the main smelting plant where it is recovered from the smoke-stacks as a by-product, while phosphate rock, for the manufacture of phosphates, is imported.

The direct current necessary for the electrolytic production of hydrogen from water is supplied by mutators at a D.C. voltage of 670 V. When deciding to employ mutators for this purpose the engineers of the Consolidated Mining & Smelting Company were not only influenced by the advantages previously cited but also took into consideration the high efficiency of mutators at 670 V and the impossibility of the mutator polarity becoming reversed during service. This latter feature, which is inherent to mutators, is of inestimable value in a hydrogen plant as it eliminates the danger of hydrogen being generated at the anodes of the electrolytic cells, instead of at the cathodes, and hence removes the danger of an explosive mixture being formed in the storage tanks.

The mutator equipment for the Warfield plant was ordered in July 1929, and comprised a total D.C. output of 20,100 kW. This output is supplied by three 10,000-A double mutator units, each of 6700 kW at 670 V, of which one was manufactured by the General Electric Company and two by Brown, Boveri & Co., Ltd. Part of the mutator room is shown in Fig. 3, the two General Electric mutators being visible in the background and three of the four Brown Boveri mutators being visible in the foreground.

Energy for the supply of the Warfield substation is, as in the case of the zinc plant substation, taken from the West Kootenay Light & Power Co.'s network at 60,000 V, 60 cycles per second. In the zinc plant regulation of the D.C. voltage between 460 and 560 V is performed by varying the voltage fed to the mutators by on-load tap-changers. For this purpose, the 60,000-V supply is stepped down to 13,200 V at which voltage tap-changing is effected. In the Warfield plant, however, tap-changing is effected in regulating transformers at 60,000 V without resort to a step-down of the voltage. The D.C. voltage of each double mutator unit is regulated in this way to suit the requirements of the cell room between 600 and 670 V, the D.C. current

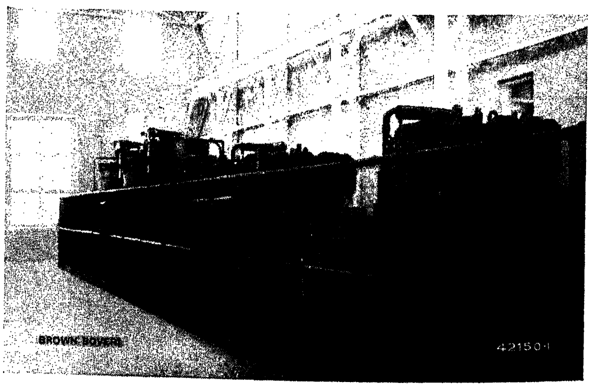


Fig. 3. — Part of Warfield mutator substation 1930, showing, in background, two General Electric mutators each 3350 kW, and, in foreground, three Brown Boveri mutators each 3350 kW.

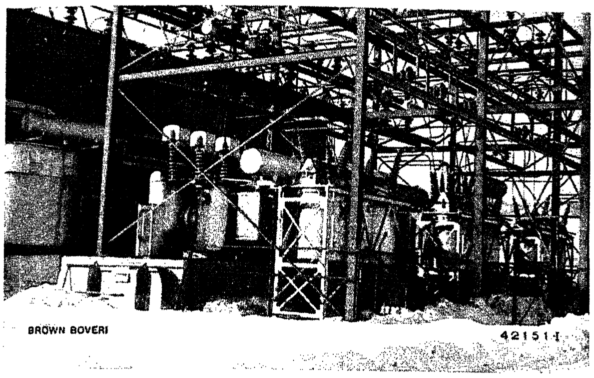


Fig. 4. — Warfield open air substation — 1930, showing, in foreground, General Electric oil circuit breakers, one Brown Boveri regulating transformer and, in background, one Brown Boveri mutator transformer.

remaining constant at 10,000 A over this range. One of the Brown Boveri regulating transformers with built-on 60-kV tap-changer is shown in Fig. 4. A 60-kV mutator transformer, in series with the regulating transformer, is to be seen on the left.

In 1935 the Consolidated Mining & Smelting Company decided to increase their production of fertiliser, and required for this purpose approximately 16,600 kW of additional direct-current power. This will be supplied by two 10,000-A Brown Boveri double mutator units, each supplying 8300 kW at 830 V. The order for this equipment was placed on the first of July 1935 for delivery within four months ex works for the first unit, five months being allowed for the second unit. Special workshop organisation was necessitated to ensure manufacture of units of this size within such extremely short periods; the first unit was ready for shipment on time on the first of October 1935 and the second unit was completed two weeks ahead of time.

Each unit comprises, in the main, a bank of oil circuit breakers, a regulating transformer, a mutator transformer, two mutators, two high and one slow-speed D.C. breakers, two D.C. smoothing coils and one switchboard.

The oil circuit breakers, shown in Fig. 5 consist of three outdoor single-pole breakers per bank with a guaranteed rupturing capacity of $1^1/_2$ million kVA at 60,000 V, 60 cycles per second. In order to avoid all danger of bushing flash-overs due to lightning, dust or other deposits, the bushings are designed for a rated voltage of 87,000 V although the service voltage only attains 60,000 V. An interesting feature of these bushings, provided at the express wish of the West Kootenay Light & Power Co., is a suction device enabling oil to be withdrawn from the lower end of the bushings without in any way disturbing the oil in the breaker. The breaker tanks and control pedestals are equipped with resistance heaters thereby ensuring service in the winter months when temperatures down to and below minus 30 °C are liable to occur.

The 60,000-V regulating transformers with built-on tap-changers vary under load the voltage fed to the mutator transformers, thereby varying the D. C. voltage furnished by the mutators. A D.C. range of 740 to 830 V at 10,000 A is required for operation of the cells. The regulating transformers have been designed to cover this range in 36 steps under the assumption that the line voltage remains within the limits of 59,000 and 61,000 V. This is normally the case but the current carrying capacity of the transformers is such that, even if the line voltage should sink to 54,600 V, it is still possible—by using the 54,600-V tap on the mutator transformer, to maintain and regulate the D.C. voltage between 740 and 830 V under 10,000 A load. The regulating transformers, as may be seen, are of the self-cooled, outdoor type and here again 87 kV bushings and tap changers have been provided as a precautionary measure.

The mutator transformers, on account of their design and size, are a noteworthy feature of the plant. Each transformer feeds two mutators and forms with them a double mutator unit of 8300 kW D. C. output; the mean transformer capacity required for this output is 11,400 kVA, which represents in itself a substantial unit. The size of the transformer is, however, considerably greater than that of a three-phase transformer of the same capacity on account of the requirements of mutator service. The secondary winding of the transformer is connected in six phase and from this

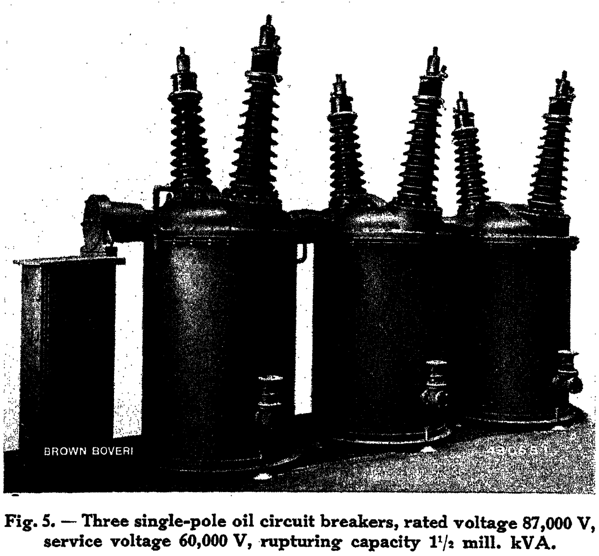


Fig. 5. — Three single-pole oil circuit breakers, rated voltage 87,000 V, service voltage 60,000 V, rupturing capacity $1^1/_2$ mill. kVA.

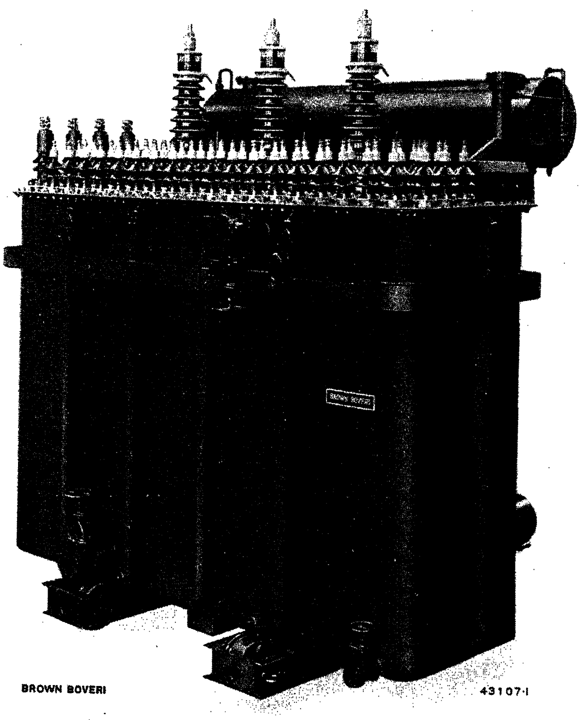


Fig. 6. — 60,000-V mutator transformer with built-in interphase reactor and anode choke coils for feeding 8300-kW double mutator unit.

winding leads are taken through anode choke coils to the 36 secondary terminals; these, in turn, are connected to the pair of 18 anode mutators fed by the transformer. The neutral points of the two component stars of the six-phase winding are joined through the interphase reactor, the middle point of which forms the 10,000-A negative pole of the double mutator unit. The 36 secondary terminals are clearly visible in Fig. 6, which shows, on the left, the four parallel terminals for connection to the 10,000 A busbar.

The mutator transformers, each of which, with oil, weighs thirty-three tons, are cooled by oil, circulated through a small pump set to a counter-flow water cooler and back to the transformer. The interphase reactor and anode choke coils are incorporated in the transformer tank so as to eliminate unnecessary bushings, tanks and cabling and are thus cooled with the main transformer.

The primary windings of the Brown Boveri mutator transformers supplied to Warfield in 1930 are connected in delta whereas the primary windings of the new transformers shown in Fig. 6 are connected in star. The latter connections were especially chosen so that the combination of the delta and star-connected transformers would reduce the 5th, 7th, 17th, 19th, etc. (series) harmonic currents which would otherwise flow in the primary network as a result of six-phase mutator operation. In this way, the advantages of twelve phase operation are attained whilst maintaining, on the other hand, the advantage of simple and robust six-phase transformer design. In order to prevent the star-connected transformers from creating third harmonics in the primary supply voltage, a small delta-connected tertiary winding is provided.

The four mutators installed in the Warfield extension are of the latest design in every respect. In this connection it is interesting to note the progress made in recent years in heavy-current mutator design. For purposes of comparison, the mutator supplied in 1929 to the zinc plant is shown in Fig. 7, the mutator supplied in 1930 to the Warfield Plant is shown in Fig. 8, whilst Fig. 9 shows the 1935 mutator execution for the extension of the Warfield Plant. A cursory glance, bearing in mind the outputs dealt with by the different mutators, suffices to reveal the great progress which has been made.

The mutators are equipped with grid control for protection against backfires and external short circuits. Grid voltage control is also provided enabling the voltage while starting the cells to be raised gradually from zero to full voltage; current surges are, thus, eliminated. Regulation of the voltage between 740 and 830 V is usually carried out by the regulating transformer as a better power factor and a smaller ripple in the D. C. are obtained by this method than

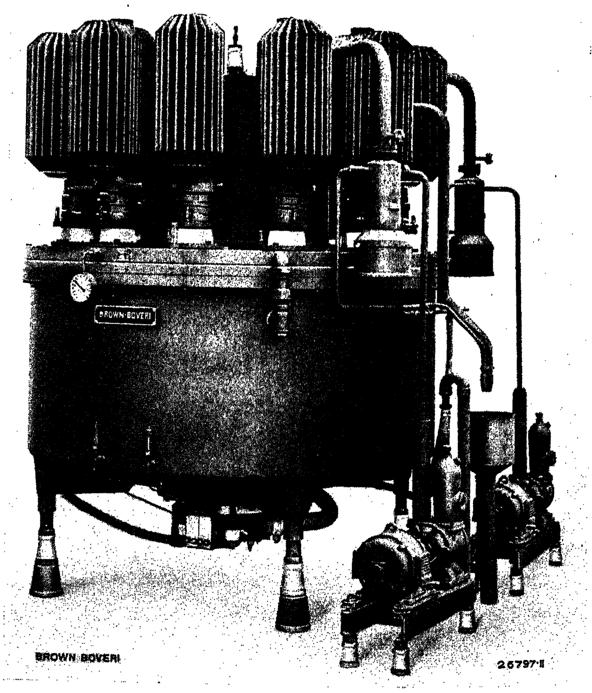


Fig. 7. — Zinc plant mutator, 2800 kW — 1929 design.

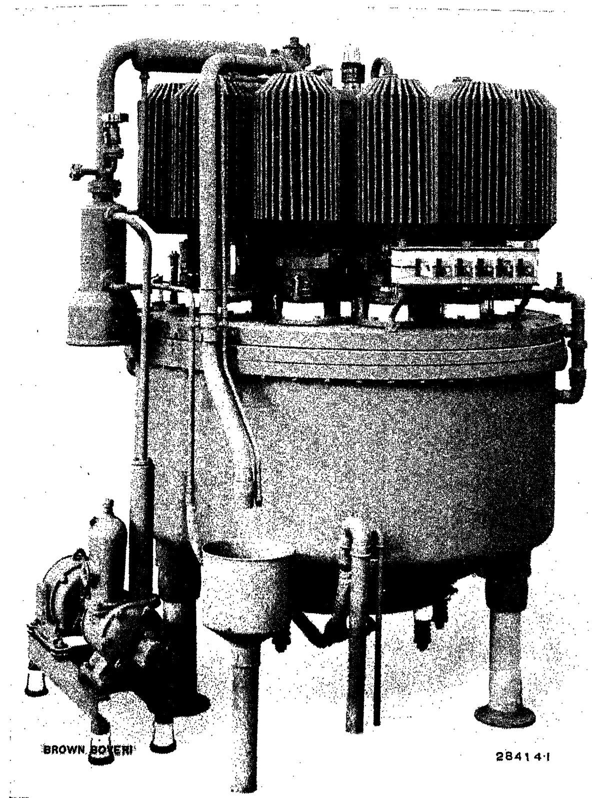


Fig. 8. — Warfield mutator, 3350 kW — 1930 design.

by grid voltage control. The grid control equipment is, however, designed to cope with continuous regulation of the voltage between 740 and 830 V, thereby presenting a valuable standby for the regulating transformers with built-on tap-changers.

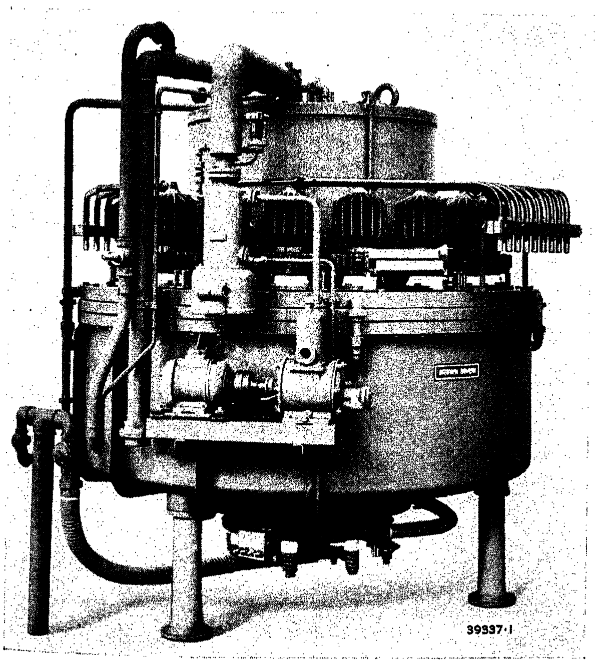


Fig. 9. — Warfield mutator, 4150 kW — 1935 design.

Cooling of the mutators, like that of the transformers, is effected by circulating the water of the mutator cooling jackets through a counterflow cooler forming part of a totally enclosed system thereby completely eliminating the possibility of impurities coming continuously into contact with the cooled surfaces of the mutators. Formation of deposits on the cooling surfaces is thus prevented and corrosion reduced to a minimum. The mutators are cooled in tandem, one cooler sufficing for a double mutator unit. The counterflow coolers are alive as they are connected with the mutators through the circulating-water piping. The coolers are, therefore, mounted on insulators and fresh water is lead to them through insulating rubber piping. Any corrosion which may take place will, thus, occur in the coolers and not in the mutators. A zinc plate is installed in each cooler and acts as a "corrosion electrode"; this plate can easily be replaced from time to time if necessary.

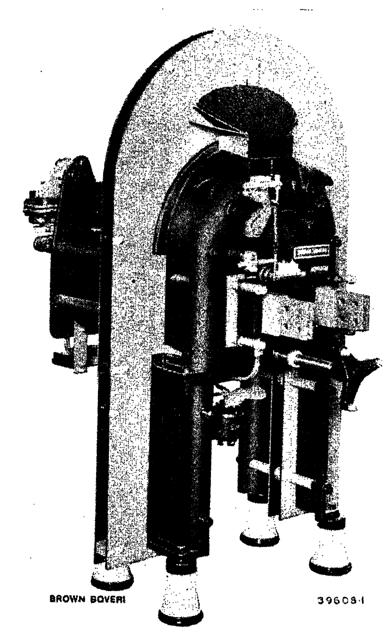


Fig. 10. — High-speed circuit breaker, rated current 6400 A.

The design of modern heavy-current mutators is such that backfires are an extremely rare occurrence. It is, nevertheless, necessary to provide high-speed D. C. breakers to protect the mutators from the effects of the heavy reverse currents which would flow from the electrolytic cells during a backfire. It is estimated that this reverse current would attain about 35,000 A and it is evident that a direct current of this magnitude could work havoc unless cut off in the shortest possible time. Fig. 10 shows the high-speed breaker which affords the requisite protection. The second mutator of the double mutator unit would feed a heavy current into the backfiring mutator but this current is immediately cut off by the grid relay which applies negative potential to the grids.

At this juncture, mention may be made that, in the plants supplied in 1929 and 1930, insufficient

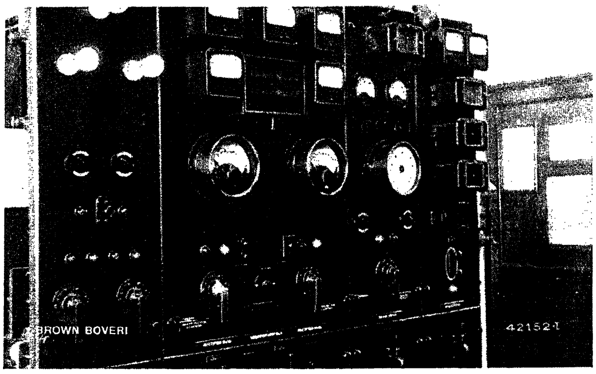


Fig. 11. — Warfield mutator switchboard — 1930 design.

attention had been paid to the operating time of the D. C. breakers. Slow speed breakers of American design had been installed and until this fact was realized, very considerable operating inconvenience was occasioned. Brown Boveri high-speed breakers, as shown in Fig. 10, were subsequently installed and satisfactory operation was immediately obtained.

All circuit breakers and tap-changers are motor-operated, so that control of each double mutator unit may be effected from a switchboard installed in the mutator room. It is interesting to compare the switchboard supplied in 1930 (shown in Fig. 11) with that supplied in 1935 (shown in Fig. 12) and to note the progress in design. It must, however, be stated that the difference between the two switchboards is partly to be attributed to the fact that the board shown in Fig. 11 was built in the U.S.A. in accordance with American practice, whereas the board shown in Fig. 12 is built in accordance with European practice. The centre panel of the switchboard carries the control switches, instruments and alarm devices for the incoming 60,000-V apparatus, whereas the side panels carry the controls for each of the mutators of the unit.

In conclusion it may be said that the total output of Brown Boveri mutators installed in the plants of the Consolidated Mining & Smelting Company now attains 46,800 kW. On large traction systems such as those of the Southern Railway, England, and the Berlin Suburban Railway, Germany, mutators of Brown Boveri design attain total outputs of between 100,000 and 200,000 kW on each of the systems in question. The above figure of 46,800 kW represents, however,

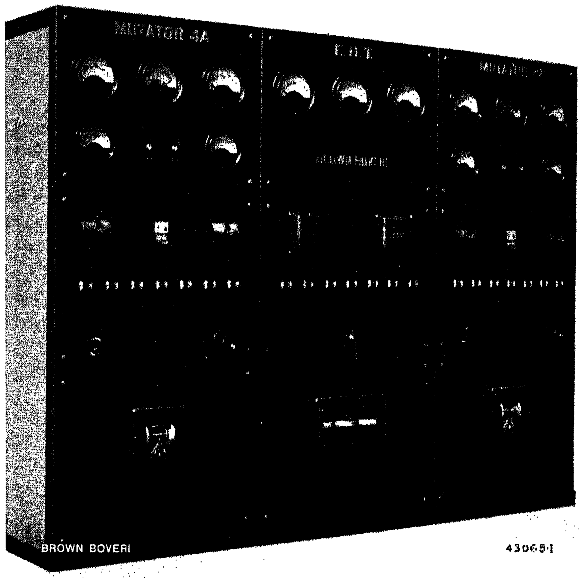


Fig. 12. — Warfield mutator switchboard — 1935 design.

the largest mutator output ever supplied by Brown Boveri to industry and is a striking example of the application of mutators to electro-chemical processes.

(MS 964) *H. C. Beck.*

NOTES.

A Brown Boveri electric boiler in the Zuckerfabrik[1] & Raffinerie Aarberg A. G., Aarberg (Switzerland).

Decimal index 621.181.646 : 664. 1.

THE accompanying illustration shows the Brown Boveri electric boiler which was put to work for the first time in October 1935 in the Zuckerfabrik und Raffinerie Aarberg A. G., Aarberg (Switzerland). This boiler is built for a rated power input of 6000 kW and for a three-phase supply at 16,000 V. It was built to produce a pressure of 18 kg/cm² gauge. When working with feed water at 80° C the full load corresponds to a production of approx. 8600 kg/h of steam.

This plant is a typical example of a Brown Boveri high-voltage electric boiler. The water is sprayed out from a central ejection pipe and impinges on metal electrodes. Both the ejection pipe and the electrodes are so designed that there is no splashing of water, which allows of avoiding short circuits and trouble in service. The special shape of the electrodes has been patented. The passage of the electric current and the consequent heating of the water takes place during the passage of the water jets from the ejection pipe to the electrodes and also during the flow off, below, of the water from the electrodes to the lower part of the boiler.

This electric boiler has been in continuous 24-hours-a-day service ever since it was taken over, including Sundays and holidays and the output has, occasionally, been increased to 10,000 kg/h of steam.

Formerly, steam generation in this sugar mill was by four inclined-tube boilers with coal firing and each of these is built for an output of 7—8 tons of steam per hour. It

[1] See translation of letter on the second page of this number.

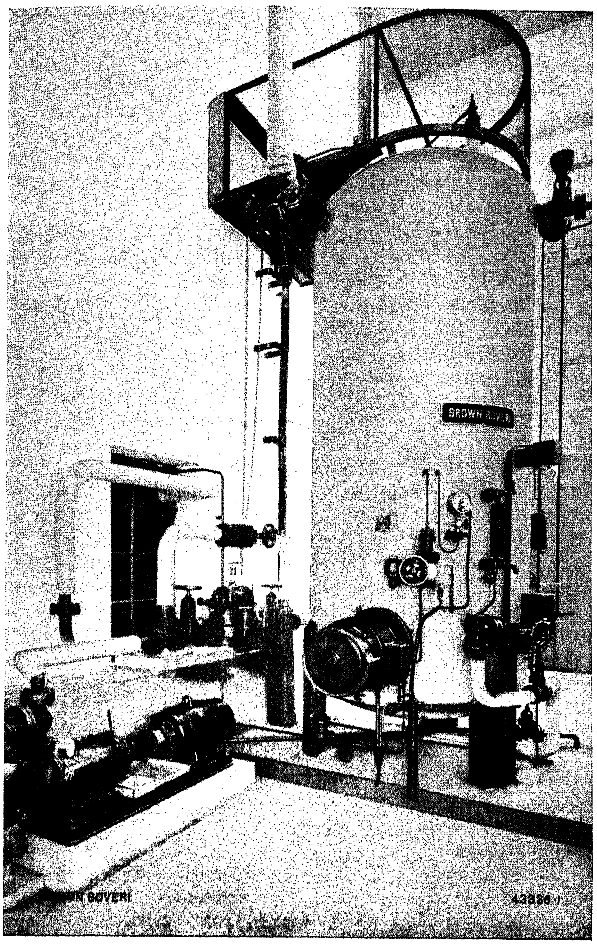


Fig. 1. — Zuckerfabrik und Raffinerie Aarberg A. G., Aarberg (Switzerland). Electric boiler 6000 kW, 16,000 V, 50 cycles, 18 kg/cm² gauge, for 8600 kg of steam per hour.

became necessary, last year, to enlarge the boiler plant; work which had to be carried out before the beet-root harvest of 1935. It would have been impossible to install boilers of the ordinary type in the time available and this caused the owners to purchase an electric boiler. This unit was delivered and put to work within four months and was in perfect working order when the beet-root harvest begun.

The electric switchgear was also delivered by Brown Boveri. It is composed of a high-tension framework with sheet-metal covering and a separate switchboard for the low-voltage part.

The Bernische Kraftwerke Co. supplies the requisite electric power.

(MS 982) *W. Roth. (Mo.)*

110-kV circuit breakers with convectors for outdoor erection, in Tasmania.

Decimal index 621.316.57.064.25.

THE Brown Boveri Review reported, lately, on the delivery of generators of large output for the Tarraleah Power Station, which is, at present, in course of erection on the island of Tasmania. The extra-high tension system of the country is being extended and altered in connection with the building of this big power station. 25 Brown Boveri oil circuit breakers, 110 kV for outdoor erection, Type OKF 22, were ordered for the equipment of the said system. In this type of circuit breaker, the arc is extinguished in convector chambers, the operation of which has been explained in various publications on Brown Boveri convector circuit breakers and should be well known. The breakers of Type OKF have the advantageous qualities of the latter, as, for example, extraordinary short duration of arc. Thanks to the small amount of gas generated at breaking, it is possible to lodge all three phases in one tank despite the high-rated voltage, which means considerable saving in space, reduction in oil filling, and in freight charges. The illustration shows a similar circuit breaker for 87 kV with its drive.

The material delivered in the present case comprises circuit breakers for current-ratings of 400 A and 640 A. Some of these will be inserted on the existing 88-kV system or else on the newly-built 110-kV system. Condenser-type bushings are used as terminals, these having porcelain covers. There are six bushing-type current transformers built into each breaker for system-protective purposes, of which all give the same three ratios of transformation which can be adjusted to on the control pedestal in order that the current transformers may be made to suit the rated current flowing at the various points on the system.

There are spring-type power-storage devices, with electric winding-up gear, for the drive of the breakers. There is a heating resistance in the control pedestal to

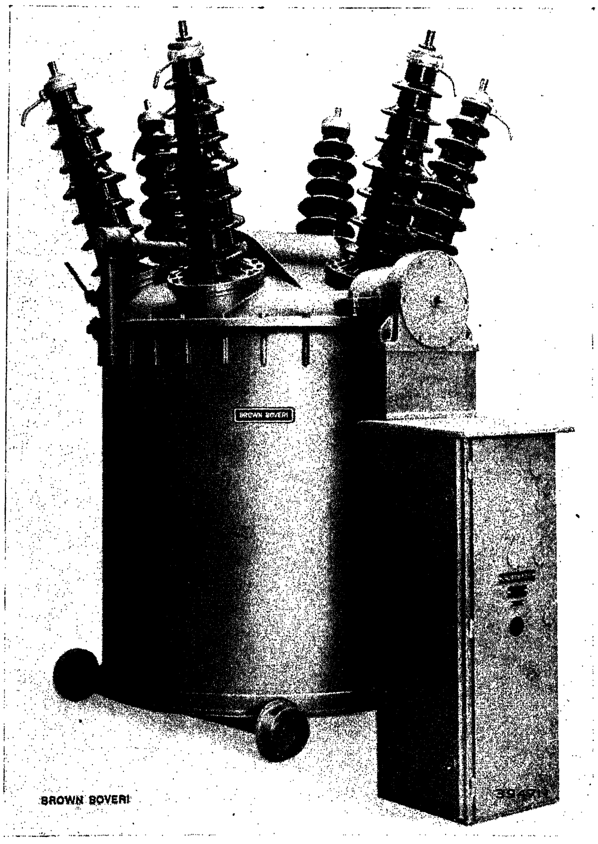


Fig. 1. — Oil circuit breaker with convector chambers, Type OKF 18, 87 kV, with control pedestal.

prevent condensate forming even under rapid falls in temperature.

Some of the circuit breakers have electrostatic voltage dividers built into the bushings, which are used to supply synchronizing instruments. Two sets of each one electrostatic synchronoscope of the Sieber type, one frequency meter and a voltmeter were delivered to the Tarraleah power station and the Creek Road Substation respectively; in the latter, the coupling of the 110-kV system to the 88-kV system is carried out.

(MS 965) *H. Vetsch. (Mo.)*

Mutators for rolling-mill service.

Decimal index 621.314.652.2 : 621.771.

In the month of April, 1935, two mutator sets each of 2500 kW were put to work in the plant of the Société des Hauts-Fourneaux, Forges et Usines de la Providence, in Hautmont (France).

This mutator plant is intended to strengthen the power plant available, consisting of old turbo-dynamo sets. The chief characteristics of the new mutator plant are:—

Output . . . 2×2500 kW,
D. C. voltage . . 520 V.
D. C. current . . 4800 A.
Overload capacity 5300 A, during 60 min.
6000 A during 30 min.
7200 A during 5 min, every 15 min.
9600 A during 1 min, every 10 min.

The output given here and the very severe overloads are delivered by mutators of the A 918 type each having 18 anodes (Fig. on cover), with anode choke coils to assure a proper distribution of current between the anodes (these coils are seen in the center of the photograph of the substation, being located between the mutators and the control switchboard).

These converter sets, designed specially for the supply of rolling-mill motors of big output, have got to stand up to heavy overloads occurring every 10 to 15 minutes. Thanks to its quality of being able to carry big overloads, the mutator is a very suitable type of machine for supplying rolling-mill motors.

The protection of mutator sets is always a problem of great importance and the more so the greater the output of the mutators. Much study was devoted to this point, in the present case, and the protective equipment employed is described herewith.

Taking into account the power of the high-voltage plants of the Usines de la Providence, in Hautmont, circuit-breakers Type OH 12, of reinforced design and capable of rupturing 500 MVA, were used for coupling up the mutator equipments to the 10,000-V bus-bars. These circuit breakers are equipped with over-current tripping gear and are remote-controlled by motor. Tripping can be effected by push-button from the control board through a tripping coil on the breaker.

There are extra-high speed breakers Type JCB inserted in the cathode leads of the mutators; these have a reverse-current automatic trip and are also remote-controlled.

Further, each mutator is protected against short circuits by polarized grids. This special protection by the Brown Boveri method makes use of a very high-speed relay 16 which reverses the polarity of the grid (Fig. 1). If a short circuit occurs in the mutator tank itself or on the D. C. side, this relay intervenes instantaneously, under the influence of the over-current from the transformers 17, and applies negative polarity to the anode grids thereby preventing the arc reigniting. The time required to suppress a short circuit does not exceed that of one full cycle, at the most.

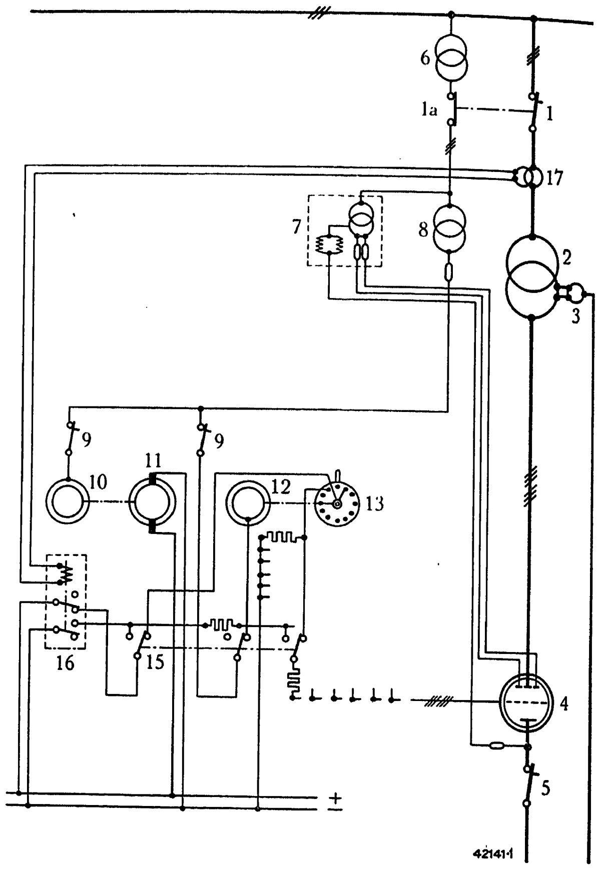


Fig. 1. — General diagram of connections. Voltage regulating devices and protective devices against short circuits by polarized grids.

One of the particular conditions stipulated by the Société des Usines de la Providence was regulation of the D. C. voltage by polarized grids within the following ranges.

Progressive regulation of D. C. voltage from zero to the rated value, allowing a motor and mutator set to start service under special conditions on the main D. C. bus-bars.

Continuous regulation of D. C. voltage at all loads, from the rated voltage down to 10% below it, to allow of adjusting the D. C. voltage when the mutator sets are to work in parallel with turbo-dynamo sets and, also for compensating fluctuations in the primary voltage.

The equipment required for voltage regulation by polarized grids is shown in the diagram in Fig. 1. This apparatus consists, in the main, of a small set composed of an induction motor and a dynamo, 10 and 11, a distributor 13 driven by a synchronous motor 12, running in synchronism with the A. C. system to which the mutator is connected. By regulating the moment the arc strikes during the positive half wave, the R. M. S. value of the voltage is regulated, as desired, which means, practically, regulation of the D. C. voltage available on the D. C. side of the mutator set.

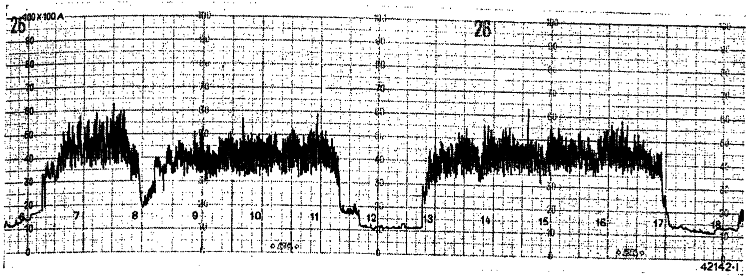


Fig. 2. — Load diagram of a mutator set.

The control apparatus for voltage regulation by polarized grids has been designed to allow of voltage regulation either from the control board of the mutators themselves or else from the control desk of the rolling-mill motors.

The devices for protection against short circuits, by means of polarized grids are co-ordinated with the apparatus regulating the voltage.

The voltage-regulating apparatus can be cut out by means of change-over switch 15, while maintaining in service the protective devices by polarized grids.

Fig. 2 gives a fragment of the load diagram of one of the mutator sets, which is characteristic of operating conditions with sudden and heavy load fluctuations:— these are conditions for which the mutator is peculiarly fitted.

The number of kW produced by all the Brown Boveri mutators used in rolling mills is increased by the addition of this new plant to a total of 40,000 kW.

(MS 963) *M. Rossé. (Mo.)*

Three-phase shunt commutator motor to drive a high-power sugar centrifugal.

Decimal index 621.34 : 664.1.057.55.

Fig. 1 shows a three-phase shunt commutator motor delivered for the drive of a high-power sugar centrifugal.

By means of very simple control, through three push-buttons, only, this motor very quickly brings the centrifugal up to the running or process speed of 1000–1450 r. p. m., without stressing the supply system by current surges. For stopping the centrifugal, the motor is retarded by electric braking down to a speed of about 500 r. p. m., so that the mechanical brake, only intervenes in the lower speed range and is, thus, saved from wear. Apart from the simplicity of control, the economical operation of the drive proved very advantageous, this in spite of the relatively low cost of power in the sugar mill. This economy is due to the practical elimination of the usual starting losses and, also to a great part of the power stored up in the rotating masses being recuperated through electric braking. As compared to drives by squirrel-cage or slip-ring motors, whether with a slip coupling or not, the ratio of the total power consumptions is about 100 : 175 as is shown by the two current consumption comparisons of Fig. 2.

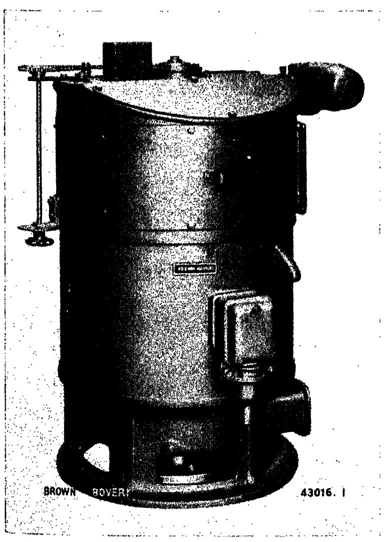


Fig. 1. — Three-phase shunt commutator motor, 37 kW, 430—1450 r. p. m., in totally-enclosed design with forced-draught ventilation.

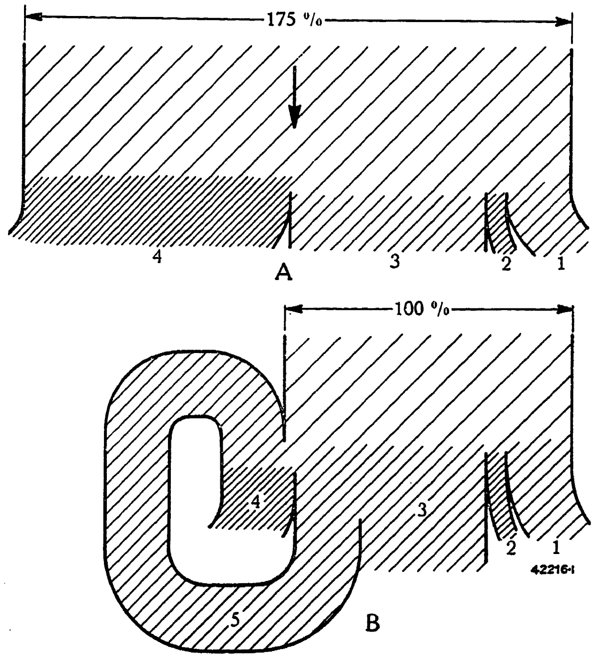


Fig. 2. — Current consumption comparison for the drive of a centrifugal.

A. By Induction motor.
B. By shunt commutator motor.
1. Effective work done by motor during the process.
2. Losses of motor during the process.
3. Effective work done by motor at starting.
4. Losses of motor at starting.
5. Power recuperated by electric braking.

From the mechanical point of view, as well, excellent results were attained with this motor which has a coupling of a new design with very flexible but tough rubber disc as transmission organ.

(MS 984) *S. Hopferwieser. (Mo.)*

Electric drives for sanforising machines.

Decimal index 621. 34 : 677. 021.

UNEQUAL tensions in warp and weft are set up in tissues in the course of manufacture and are due to the various stresses to which they are subjected during the weaving process proper and the subsequent processes, such as dyeing washing and bleaching. The result is that these stuffs shrink when washed. The process known as sanforising has as object the removal of the unequal tensions

from the tissue by shrinking and, thus, preventing the stuff shrinking later on again. The amount of shrinkage necessary depends on the kind of cloth handled and the speed with which it has to be passed through the sanforising machine is dependent on this.

For the reasons first given, it is necessary to vary the speed of the driving motor smoothly, without steps, and over a wide range, independently of the load. Supervision of the motor must be made as simple as possible so that the operator can give his full attention to the sanforising machine. These conditions are best fulfilled by the three-phase shunt commutator motor with electric remote-control equipment (Fig. 1). D. C. motors in Ward-Leonard or in positive and negative booster connection can also be used, but this means using a converter set and the consequent conversion losses, which are unavoidable, must be reckoned with. This second solution has the additional disadvantage of requiring more apparatus. For these reasons, the three-phase shunt commutator motor deserves to be given preference. Brown Boveri has already equipped a whole series of sanforising machines with drives of this type and all have given the most satisfactory results. The push-button control is especially appreciated as it makes for easy and certain control of all the processes and allows the machine to be used to greatest advantage, in accordance with the different conditions it can be called on to work under. The main switch and contactor are lodged in a switch cubicle along with the control apparatus and fuses of the necessary electric auxiliary drives and devices. The good practical results recorded with sanforising machines thus driven are yet another proof that it is well worth while to introduce variable-speed electric drives in textile finishing plants, as well. Machines such as calanders, stentering frames, mercerizing machines and the like which operate at different speeds can only be utilized to the fullest extent if the drives with which they are equipped are both reliable and very adaptable.

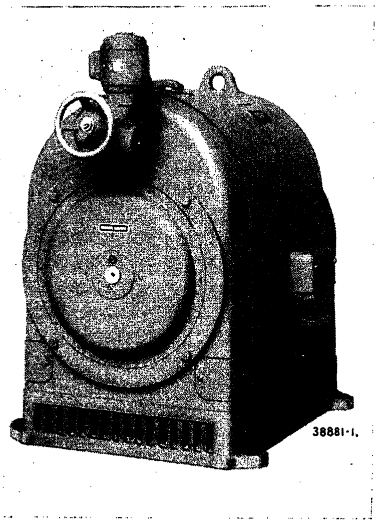


Fig. 1. — Three-phase shunt commutator motor, Type PNR with electric remote control of the brushes. Range of speed variation 262—1570 r. p. m.

(MS 958) *H. Wildhaber. (Mo.)*

Some recent orders for automatic regulators.

Decimal index 621. 316. 722.

THE Brown Boveri automatic quick-acting regulator is being used, more and more extensively, in the most varied kinds of plants, not only in conjunction with Brown Boveri machinery but along with machinery by many other makers. This broadening of the field of utilization is due to the well-known qualities of the Brown Boveri regulator, namely:— great precision, absolute reliability, no parts which wear down, no supervision required, easy adaptability, etc. During recent years, only 25 to 30 % of regulators delivered have been for plants with Brown Boveri machinery, 70 to 75 % being for fitting to machinery by other makers.

It might have been expected that the present economic crisis would have brought about a fall in the number of regulators ordered, in conjunction with the reduced number of new generators being built. This has not been the case; the number of regulators ordered has, certainly, fallen off, but to a far lesser degree than that of the generators. This is due to the gradual but general recognition of two facts:— firstly, that it is necessary to put automatic regulation into older plants which worked to hand regulation up till now and, secondly, that no great capital is required for fitting automatic regulating gear. To this must be added the growing recognition of the undeniable qualities of the Brown Boveri automatic regulators of the new design.

Quite recently, Brown Boveri got some orders for their automatic regulators which are interesting from the point of view of the special operating conditions called for as well as from that of the extent of the order itself.

Mention should be made of the following orders among those given for A. C. automatic regulators.

The *Italian State Railways* gave Brown Boveri's Italian concessionaries the Tecnomasio Italiano Brown Boveri, Milan, an order for six complete regulating equipments intended for three synchronous condensers each of 10,000 kVA, 630—750 r. p. m., 42, 45 or 50 cycles, to be put in three substations for supplying newly electrified line sections. Tecnomasio Italiano Brown Boveri is only supplying one of the three condensers but the railways insisted on a uniform regulating and protective system and a uniform automatic paralleling system on all the machines. A comparison between different designs and the practical experience gained in plants running proved that the Brown Boveri system had the greatest number of advantages and this dictated its choice.

The synchronous condensers are specially intended for voltage regulation and are built to be over- and under-excited so as to allow of using them over a wide range, they have pilot exciters in order to impart to the excitation that stability which is required under low excitation. The voltage regulator, inserted between the pilot exciter and the main exciter, is designed to allow completely automatic regulation between zero excitation and maximum excitation corresponding to full load under over-excitation and this without it being necessary to make any commutations or hand regulation. Further, the synchronous compensators can carry very considerable overloads, such, for example, as 100 % for 1 min; 50 % for 3 min and 20 % for 10 min. To protect the machines against dangerous temperature rises under excessive overloading, there is a thermal relay which acts on the current-limiting regulator to regulate this apparatus to act under different values according to the temperature of the windings. The synchronous condensers are, also, equipped with the usual protective devices against excessive voltages and against

earthings in the stator or rotor circuits; a differential protection produces cutting out and rapid suppression of excitation if an internal fault occurs in the machine.

British Brown-Boveri Ltd., London got an order for eight quick-acting regulators from the *Victoria Falls & Transvaal Power Co.* Six of these are of type AB 4/1 and two of Type AB 2/1, all being for the *Klip power station.* These regulators are for six main turbo-alternators each of 40,000 kVA, 10,500 V, 3090 r. p. m., 51·1 cycles and for two auxiliary sets each of 8750 kVA, 2100 V, 3090 r. p. m., all British built machines.

Simple and rugged automatic regulators, giving the highest degree of reliability and requiring neither supervision nor overhauling are an absolute necessity in overseas plants of this size, in the remoter districts, where skilled labour is not easy to get and where it takes time to replace damaged parts.

The *Steyrische Wasser- und Elektrizitäts-A.-G.* in *Graz* ordered from Brown Boveri, Vienna, four quick-acting regulators Type AB 4/1 for three alternators each of 13,000 kVA, 750 r. p. m. and for an alternator 1900 kVA, 250 r. p. m., all built by another maker, which are in the *Arnstein* and *Teigitschmühle* power stations. These plants were, formerly, equipped with regulators of the vibrating-contact type, while the *Pernegg* and *Mixnitz* power stations, belonging to the same Company and having alternators of 8000 kVA, 5250 V, 150 r. p. m. and of 11,000 kVA, 5250 V, 214 r. p. m., also built by other makers, were equipped with Brown Boveri regulators. The deciding factor in the replacement of the regulators with vibrating contacts by Brown Boveri regulators was the very satisfactory results obtained with the latter.

The *Société Edison, Milan,* ordered from Tecnomasio Italiano Brown Boveri the necessary equipment for automatic regulation and protection of two alternators each of 20,000 kVA, 504–600 r. p. m., 42/50 cycles built by the T. I. B. B. These regulators are of the new high-power type described in the Brown Boveri Review, August number, 1934, while the current limiting regulators are of Type A 4/3.

The *Ateliers de Jeumont* give our French concessionaries, the Cie Electro-Mécanique, Paris, an order for the equipment for automatic regulation of a synchronous condenser, 20,000 kVA, in the *Creney station* located at the end of the 220-kV transmission line from Kembs on the Rhine. In accordance with the system proposed for this network, the automatic regulator is designed for extra-rapid excitation by a separate quick-response winding. Although they never promoted this extra-rapid excitation, the advantages of which are very problematic, Brown Boveri were able to produce regulating devices to meet the conditions imposed by this kind of excitation.

Finally, mention should be made of an order given by the *Azienda Elettrica del Governatorato di Roma* to Tecnomasio Italiano Brown Boveri, Milan, for 10 regulating equipments, each of one voltage regulator, one current-limiting regulator and protective relays all for different alternators built by T. I. B. B. and others and running in power stations near Rome. This order means that all the steam and hydraulic power stations near Rome are now equipped with Brown Boveri quick-acting voltage regulators and Brown Boveri current-limiting regulators. The total numbers of Brown Boveri regulators in the said region amounting to about 60.

Among the *D. C. regulating equipments* mention can be made of an order given by l'*Usine de Produits Chimiques et Electrométallurgiques d'Alais, Froges et Camargue* to the Cie Electro-Mécanique, Paris, for the equipment of the *Saint-Jean de Maurienne* works with:—

four automatic current-limiting regulators Type AB 2/0;
two complementary regulators Type AB 2/0;
two automatic voltage-limiting regulators Type A 4/0.

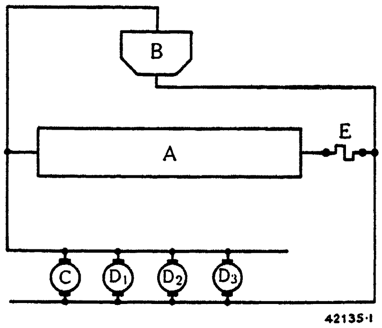


Fig. 1. — Diagrammatic layout of the mixed supply of a series of aluminium furnaces by means of mutators and dynamos.

A. Series of furnaces.
B. Set of mutators.
C. Dynamo driven by hydraulic turbine.
D_1, D_2, D_3. Dynamos driven by induction motors.
E. Shunt.

These regulators will be used for four D. C. generators by other makers each built for 250 V, 5000 A, 375 r. p. m. and working under the following conditions (Fig. 1):—

The series of furnaces A is supplied, on the one hand, by one or by several mutator sets B and, on the other, by a certain number of generators C and D which are driven by hydraulic turbines or induction motors. The hydraulic sets have no speed governors and, thus, work to constant output, that is to variable current strength, according to the terminal voltage; they, also, have no electric regulators.

Since the total current must be kept constant and the resistance of the circuits being fed is always changing, voltage regulation of the machines becomes necessary and automatic regulation desirable.

The mutator sets B are provided with a device to make them deliver constant current and, therefore, they need not be taken into account in the regulation of the rotating machines. On the other hand, the generators of the rotary sets without speed governors cause variations in the current which must be balanced by the generators of the converter sets. The latter can, thus, be called on to work in two different ways.

(a) To constant current regulated between 2000 and 5000 A, as desired.
(b) To variable current, but limited to 5000 A, to make up the current delivered by the other generators and maintain the current through the shunt E at a constant value.
(c) Lastly, as is the case for all the other generators supplying the series of furnaces, the voltage must not exceed a certain value, which can be regulated as desired between 250 and 300 V.

To meet the conditions just set out the following device has been provided.

(a) Each generator has a current regulator allowing the current to be maintained at a constant value between 2000 and 5000 A.

(b) The shunt E supplies a complementary regulator which, in turn, acts on the current regulators of the sets which should operate at variable current so that the current through the series of furnaces is maintained at a constant value between 30,000 and 45,000 A.

In this case, the current regulator also plays the part of a current limiter, that is to say it prevents the current delivered by the machines exceeding the allowable maximum of 5000 A.

(c) Finally, a voltage limiter acts simultaneously on all the current regulators working, so as to limit the voltage to any value desired, between 250 and 300 V.

As the generators can work, alternatively, on two series of furnaces, there are two sets of complementary regulators and of voltage limiters.

Lastly, mention should be made of an order placed with Brown Boveri by the *S. A. pour l'Industrie de l'Aluminium of Neuhausen* for four current regulators Type AB 4/0 for regulating four D. C. generators by other makers, each built for 3000 kW, 350 V and working in the *Chippis* works (Canton Valais). The object of these regulators is to maintain constant current delivered by the machines, in spite of fluctuations in the resistance of the circuit they work on, which is composed of a series of aluminium furnaces. All these generators are driven by synchronous motors, which simplifies the regulating apparatus. These regulators were ordered thanks to the excellent results attained with six similar ones delivered some time ago to the Sava Company, an allied concern of the S. A. pour l'Industrie de l'Aluminium, Neuhausen, and used for regulating similar generators in the Porto-Marghera works near Venice.

(MS 960) *W. Marolf. (Mo.)*

Velox steam generators for New Zealand.

Decimal index 621. 181. 39 (931).

THE Wellington City Corporation has recently placed an order for two Brown Boveri Velox steam generators intended for its steam power plant at Evans Bay.

The power requirements of the city are ordinarily supplied by three distant government hydro-electric stations over a 110-kV transmission system. At certain times of the year severe storms are experienced, and although failures of the transmission system due to this and other causes are not frequent, they are a source of great anxiety when they do occur. These considerations together with the still fresh experience of the last earthquake have caused the Corporation to decide on the installation of quick-starting, stand-by generating plant in the existing thermal station, to supply the power requirements of the essential services in an emergency.

The choice of the type of equipment was made the subject of an exhaustive study by the client and his consultants, Mssrs. Preece, Cardew & Rider of London. The result of this investigation was a decision in favour of a quick-starting steam plant of 15,000 kW output with two Velox steam generators, each for a normal full-load evaporation of 41 t/h and a maximum evaporation of 45 t/h. This arrangement provides for meeting up to about 60 % of the full-load steam requirements by means of one Velox boiler only.

The purchaser's specification called for a starting period of not more than ten minutes: the guaranteed starting time at which the Velox steam generators can in an emergency be brought from the cold state to producing the full-load steam quantity at normal pressure, however, is only five minutes. This exceedingly short starting time was by far the shortest compared with those offered by any of the competing firms. This feature is one of the many advantages typical of the Velox steam generator and was largely responsible for the Corporation's decision in favour of the Velox boiler.

The normal steam conditions are 17 kg/cm² abs and a temperature of 345° C. The guaranteed efficiency with a feed-water temperature at the economiser inlet of 65° C is 92·5 % at full load and 91·5 % at half load. As mentioned, they will have a normal-rated evaporative capacity of 41 t/h and a maximum capacity of 45 t/h.

Some idea of their compactness is obtainable from the fact that each Velox generator complete with auxiliaries occupies only about 2/3 of the floor space of the existing 13 t/h water tube boilers, i. e. of boilers having only one third of their output. They are designed for oil firing with any commercially obtainable grade of fuel oil.

The Velox steam generator, whether for peak load, or for stand-by service, or for both as for example the installation now under construction for the City of Oslo,[1] represents the ideal solution for such duty. Not only is it instantly available for service, but it is also very economical due to its high efficiency and to the avoidance of all banking losses.

(MS 974) *H. S. Hvistendahl.*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2) : 621. 313. 322.

THE electricity works of the town of Aarau (Switzerland) were supplied with two two-phase generators, in the year 1905 and these machines are still running to-day. They are of type B 5000/96, output 500 kVA, 2000 V, 125 A, 38·5 cycles at 48 r. p. m. They are of the vertical-shaft type with rotating pole wheels and separate excitation. One of the two machines was rewound, in the meantime, for three-phase A. C. current, 8000 V, 50 cycles.

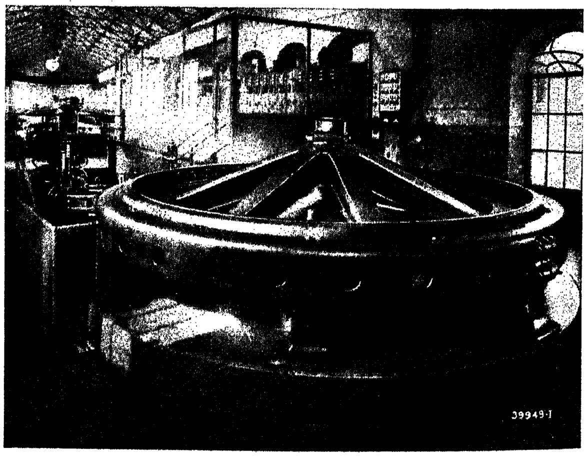


Fig. 1. — Aarau Electricity Works. Two-phase generator Type B 5000/96, 500 kVA, 2000 V, 38·5 cycles, 48 r. p. m., delivered in 1905.

The illustration shows both generators.

(MS 947) *Prop.*

[1] Brown Boveri Review 1935, No. 8, page 164.

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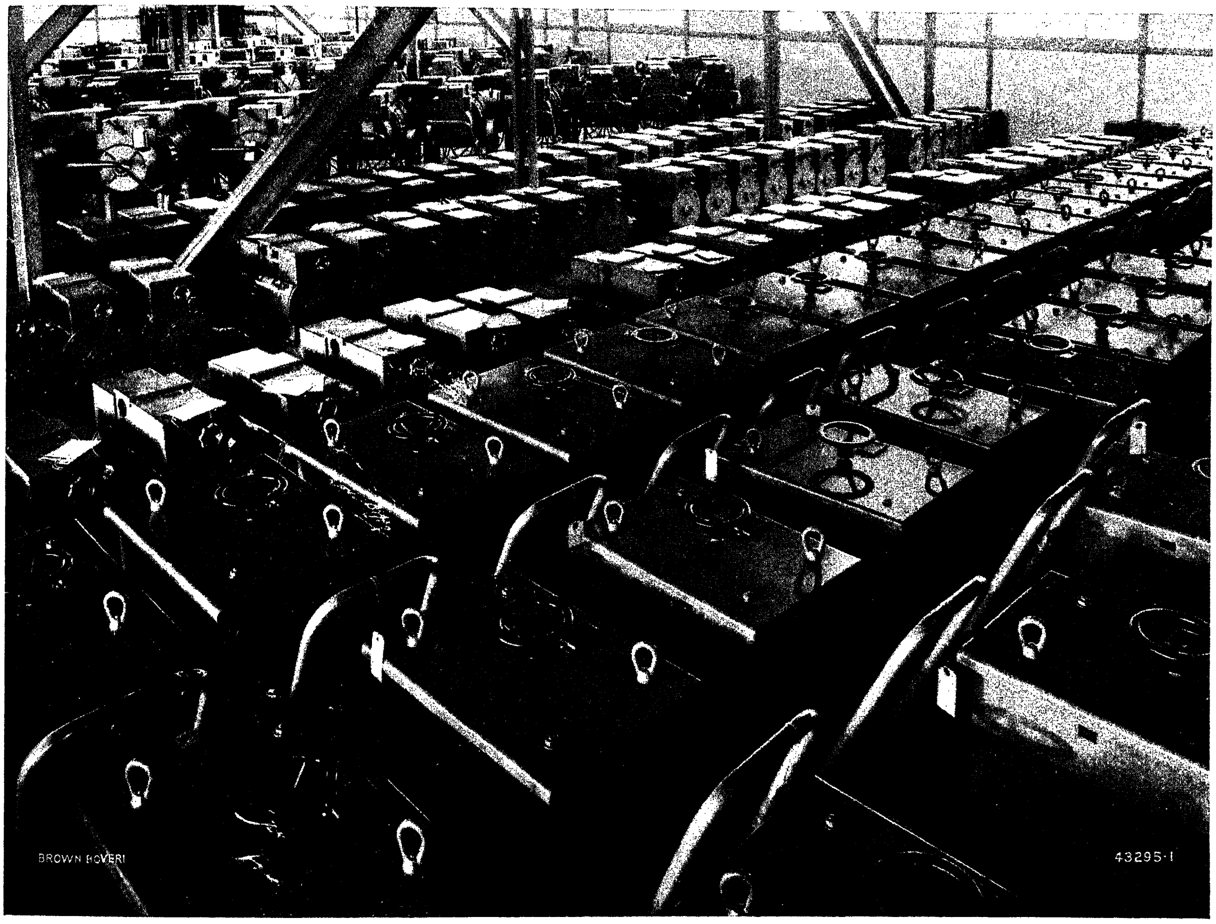

BROWN BOVERI WELDING MACHINES READY FOR DESPATCH.

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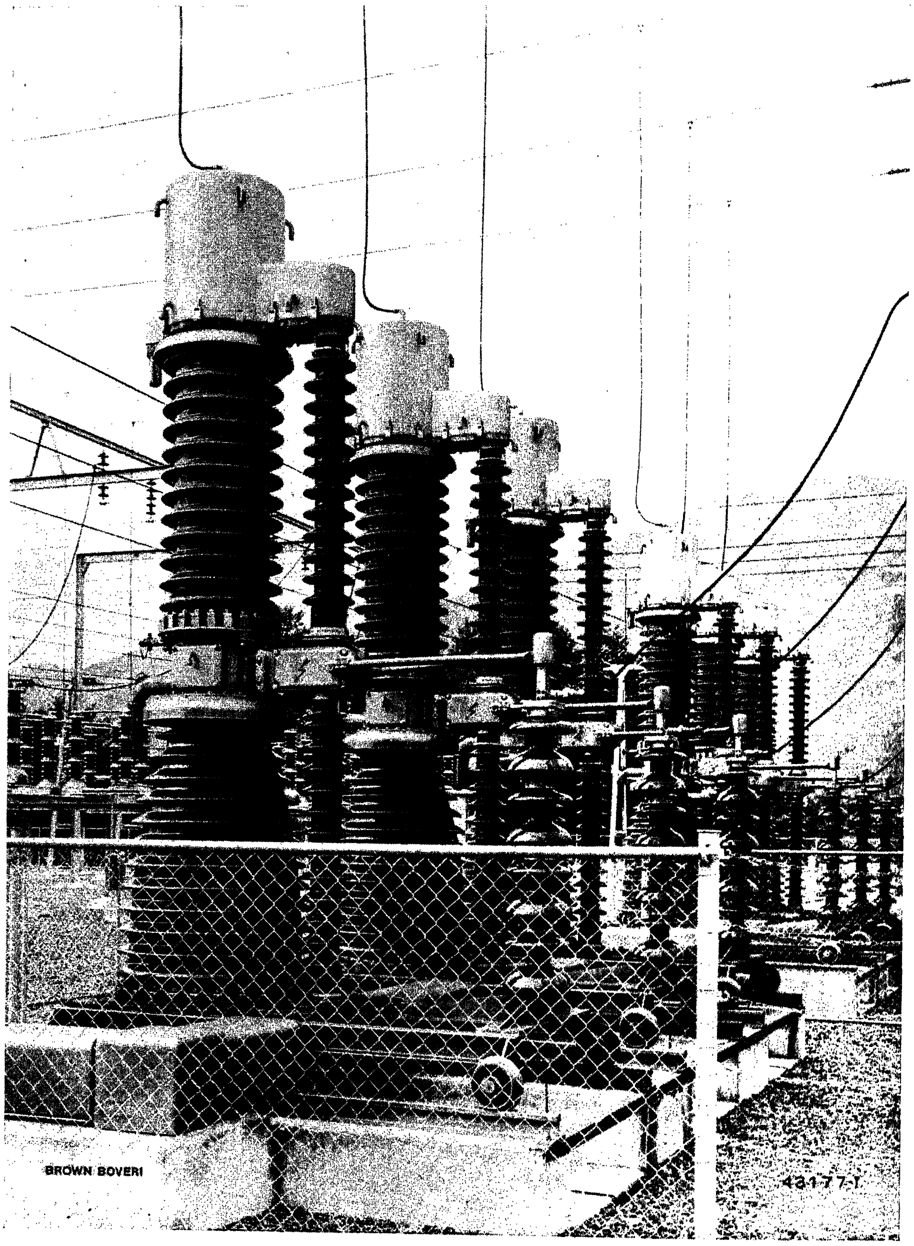
BROWN BOVERI HIGH-VOLTAGE SWITCHGEAR



Energie Ouest Suisse, S. A., Lausanne.
Convector circuit-breaker set, 135 kV in the St. Triphon substation.

High-voltage circuit breakers
Spring-operated and motor-operated remote-control
Current and voltage transformers - Transmission-line equipment
High-voltage fuses - Excess-voltage arrestors

THE BROWN BOVERI REVIEW

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RESULTS OF TESTS CARRIED OUT ON A 36,000-kW STEAM TURBINE, 120 kg/cm², 480°C WITH INTERMEDIATE SUPERHEATING AND EXTRACTION, DELIVERED TO THE WITKOWITZER BERGBAU- UND EISENHÜTTEN-GEWERKSCHAFT[1].

Decimal index 621.165—174.1 (43).

TEN years ago, a steam turbine built by Brown Boveri for the Langerbrügge Power Station of the Centrales Electriques des Flandres et du Brabant and working with live steam at 50 kg/cm², 440° C, 36 t/h was put into service. This was the first application of highly-superheated high-pressure steam in a Continental power-station. The extremely satisfactory results attained with this high-pressure unit, which aroused general and well-deserved interest, was the first step in a stage of steam-turbine development characterized by the increasing use of high-pressure, highly-superheated steam.

The 36,000-kW condensing turbine built by Brown Boveri for the Karoline Pit of the Witkowitzer Bergbau- and Eisenhütten-Gewerkschaft is a milestone in the said development stage. As far as is known, it is still, to-day, the only steam turbine of such big output, in Europe, which operates with a steam pressure of 120 kg/cm² and at the high steam temperature of 480° C at the inlet and which has, already, been running perfectly in continuous service for several years. The reliability of this unit is proved by the fact that it ran for 7823 and 7970 hours respectively in the calendar years 1933 and 1934.

The exceptional operating reliability of this 36,000-kW Brown Boveri turbine is due to a number of constructive features which simplify the design and allow of utilizing the high live-steam temperature safely and advantageously. The acceptance tests also showed that from a thermo-dynamical point of view the turbine is so successfully designed that the advantages of thermal economy due to the high steam pressure and to the high steam temperature are taken full advantage of in this condensing unit with its intermediate superheating and feed-water heating by means of extraction-steam.

The author of this article was called on by the owners to examine the high-pressure steam plant, in February 1933. It was tested with and without intermediate superheating and also with and without feed-water heating by extraction steam, so that the tests allow of estimating the thermal-economic value of this additional process.

I. DESIGN OF THE TURBINE.

The condensing turbine which was the object of these tests (Fig. 1) has a normal rated speed of 3000 r.p.m. It is of the three-cylinder type, the low-pressure

[1] Extract from an article published in the Elektrizitätswirtschaft, year 1935, No. 13.

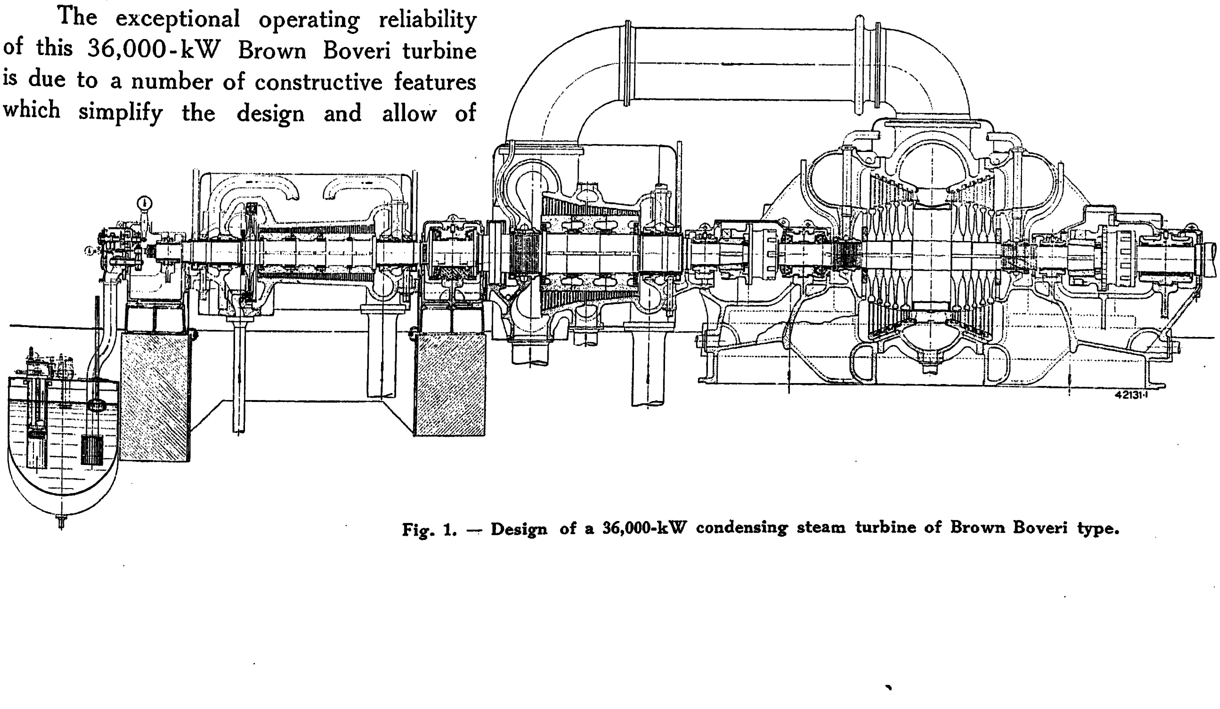

Fig. 1. — Design of a 36,000-kW condensing steam turbine of Brown Boveri type.

cylinder being of double-flow design and is built for a live-steam pressure of 120 kg/cm² abs, 480 °C at the inlet nozzles, for intermediate superheating up to 360 °C at the inlet into the intermediate cylinder and with two extraction branches for feed-water heating, of which, usually, only the low-pressure extraction branch is used in service. Table I gives the material used in the construction of the turbine as well as the number and dimensions of the stages and their distribution between the high, intermediate and double-ended low-pressure cylinders.

TABLE I.

Blading and materials used in the construction of the condensing turbine.

Cylinders	I	II	III (double flow)
Number of stages and diameter	1 Curtis 2 rows 1000 mm 32 react. stages 540 mm mean diam.	18 react. stages Reaction 1020 mm mean diam.	2×6 react. stages 1435 mm mean diam.
Peripheral speed u in m/s	Curtis disc 157 React. stages 85 mean diam.	160 mean diam.	225 mean diam.
Σu^2 . . . . m^2/s^2	283,000	433,000	304,000
	for the whole turbine 1,020,000		
Height of runner blades mm	Curtis disc 28/35 React. stages 41/86	55/215	88/365
Materials used:			
Cylinder	Molybdenum cast steel	Cast steel	Cast steel
Runner	Ni Cr steel	Ni Cr steel	Ni Cr steel
Distributing apparatus . .	High-pressure nozzles: Ni steel other stages: chromed steel	Chrome steel	Brass
Blading of runner . . .	Curtis disc Ni Cr-Molybdenum steel Other stages; chromed steel	1st to 13th stage : chromed steel 14th to 18th stage: rust-proof steel	1st to 2nd stage: chromed steel 3rd to 6th stage: rust-proof steel

The live-steam reaches the two main stop valves through two pipes. The supply of steam is governed by four sets of oil-controlled nozzle valves designed for 10,000, 20,000, 30,000 and 36,000 kW. The main valves as well as the regulating valves are mounted on the left and on the right of the turbine and so connected to the casing through flexible pipes that no thrust is exercised on the turbine. This arrangement leads to a simple design of the high-pressure cylinder and allows free, evenly distributed expansion of the casing.

The first high-pressure stage consists of a Curtis wheel with two rows of blades while all the following stages work on the reaction principle. The high-pressure nozzles for the Curtis wheel are lodged in nozzle chests set into the high-pressure casing (Fig. 1). In this way, the live steam, for which a temperature of 500 °C was calculated, is prevented from coming into direct contact with the high-pressure casing proper. This holds good as well for the maximum turbine load of 36,000 kW as, in this case also, the steam is first expanded in the Curtis wheel and is not led directly to the reaction blading without passing through the Curtis wheel at all, as is done in many turbines.

The Curtis wheel has the further advantage that the considerable drop in pressure and temperature, which take place in it, relieve the front high-pressure gland so that it is possible to give ample play in the labyrinth elements of the latter. Finally, the Curtis wheel with its two rows of blades allows the turbine to utilize completely, in three cylinders only, the considerable heat drop from 120 kg/cm² abs, 480 °C down to vacuum, including the increased drop created by intermediate superheating, which simplifies the design of the turbine and eliminates the losses which would be caused by two further sealing glands on a fourth cylinder. The rotor blades of the Curtis wheel are milled out of one piece along with the spacing and shrouding element and have a very heavy profile; according to the data supplied by the builder they are rivetted into the disc and are welded together in segments of two pieces, above, and also welded to the rim of the wheel, below, in order that the whole should be very rigid, in consideration of the deflective forces encountered and to eliminate vibrations (Fig. 2).

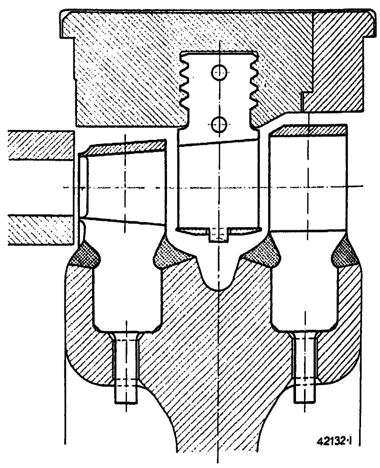

Fig. 2. — Curtis wheel for live steam at 120 kg/cm² abs, 480 °C.

As already said, the turbine under investigation works to the reaction principle entirely, abstraction made of the single impulse wheel, this having been Brown Boveri practice since many years even for high-pressure units. The reaction part of the high-pressure rotor is a practically cylindrical drum. There are no rotating discs and the big heat-conductive section makes for an even temperature distribution. As, in the reaction design, the housing has no diaphragms, the construction is made very simple.

The condensate delivered by the condensing plant is heated up to about 85° C in a surface-type apparatus inserted on the pressure pipe of the condensate pump, this by means of steam extracted between the intermediate and low-pressure cylinder. For heating the condensate to a still higher temperature, a second extraction branch is provided after the eleventh stage of the second cylinder; during the tests being described, this extraction branch was cut out. The condensate formed by the (extraction) steam from the feed-water heater is led to the flow of main condensate and reaches the boiler house in a common pipe with the main condensate.

The steam generators are Löffler boilers. The intermediate superheating of the main steam is by condensing live steam. The intermediate superheater is close to the turbine. Like the Löffler boilers, it was built by the Witkowitzer Iron Works.

II. TESTING PROGRAMME.

As the turbo-set being tested was only able to deliver power to the supply system alone during the tests, it was impossible to take measurements with the 30,000-kW load which is the most economical rating. Other loads such as about 25,000 kW and about 19,000 kW could not be held to constantly and in these cases, as well, small load fluctuations of short duration had to be taken into account. At each of the two latter loads, three tests were carried out, the turbine being operated:—

(a) with intermediate superheating and with one extraction branch for feed-water heating;
(b) with intermediate superheating but without extraction;
(c) without intermediate superheating and without extraction.

In this way, the influence of the additional superheating process on the steam consumption and especially on the heat consumption per kilowatt-hour was determined by test. The results of the series of tests at about 25,000-kW load will now be given, those resulting from the series of tests at about 19,000-kW load not producing any new facts of importance.

The precision wattmeter, current and voltage transformers used for the measurement of the electric output were all calibrated just before the tests began. The generator losses, output for auxiliary fans for generator cooling as well as the power consumed by bearing friction, by the drives of governor and turbine oil pump were all taken into account in the calculations and at the values given for them by Brown Boveri.

The steam consumption was determined by condensate measurements in calibrated measuring containers.

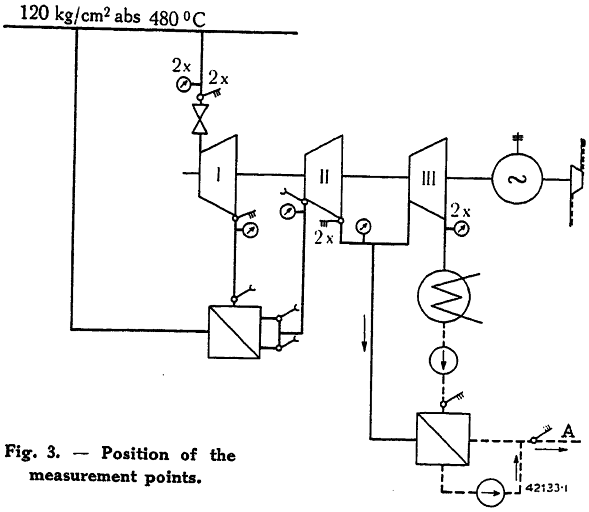

Fig. 3. — Position of the measurement points.

Pressure and temperature measurements took place at the points designated in Fig. 3. Essential measurements were made in duplicate, for subsequent checking; there were no inadmissible deviations observed. All precision manometers with big scales used, mercury thermometers, thermo-elements with the precision millivoltmeter belonging thereto, were carefully calibrated.

The tests lasted, on each occasion, 40 to 75 minutes. In the measurements of condensate, quantities of water and time were under continual observation. Wattmeter readings were taken every minute, pressure and temperature readings every five minutes.

III. TEST RESULTS.

Thermal efficiency of the turbine. — Table II contains the most important measurement readings. Main test, No. 1, gives a specific steam consumption figure of 3·22 kg/kWh, at the generator coupling. The steam was then at 120·7 kg/cm² abs and 477° C at the main inlet valve of the turbine; intermediate superheating took place at 350° C at the inlet to the intermediate pressure cylinder, with 0·054 kg/cm² abs in the exhaust branches and with condensate heating to 86·2° C by extracted steam. The specific heat consumption of the turbine was then 2477 kcal/kWh at the coupling.

If, now, the measurement results of the three tests are calculated in order to compare them on the same basis, with regard to live-steam conditions (120 kg/cm² abs, 480° C) and the same vacuum, and if the same thing be done with regard to tests 1 and 2 as regards intermediate superheating (360° C) and if

TABLE II.

Results of measurements.

Test No. Intermediate superheating/ feed water heating	1 with/with	2 with/ without	3 without/ without
Output at generator terminals in kW	24,940	25,411	22,656
At p. f. = ...	0·763	0·761	0·723
Output at generator coupling in kW	26,050	26,522	23,822
Total steam consumption of turbo-generator measured in kg/h	83,905	83,825	83,070
Specific steam consumption of turbo-generator measured			
referred to output at generator terminals in kg/kWh	3·364	3·298	3·666
referred to output at generator coupling in kg/kWh	3·221	3·160	3·487
Pressure:—			
Before main stop valve of turbine (mean value of left and right side) in kg/cm² abs	120·7	121·1	121·6
Behind regul. valve 1 and in nozzle chamber1 in kg/cm² abs	119·3	119·6	119·6
In chamber of 1st wheel, 1st cylinder in kg/cm² abs	40·3	40·2	39·3
Outlet from 1st cylinder in kg/cm² abs	11·39	11·06	8·59
Inlet to 2nd cylinder in kg/cm² abs	9·52	9·51	8·26
Between 2nd and 3rd cylinder in kg/cm² abs	0·79	0·88	0·81
In exhaust branches (mean from both) in kg/cm² abs	0·054	0·054	0·052
Steam temperature:—			
Before main stop valve of turbine in ° C (mean value of left and right sides) .	477·2	476·5	474·7
In nozzle chamber 1, accord. to throttling curve, in ° C	476·0	475·6	473·7
Outlet from 1st casing „ „	227·5	227·7	204
Inlet to 2nd casing „ „	350·0	350·4	204
Outlet from 2nd casing „ „	103·5	113·3	93
Condensate temperature:—			
Inlet to feed-water heater in °C	33·7	33·7	32·5
Outlet from feed-water heater in ° C	86·2	—	—
Heat content of steam:— (Knoblauch, 2nd edition)			
Before main stop valve of turb. in kcal/kg	790·1	789·5	788·0
Outlet 1st cylinder	689·2	689·6	679·8
Inlet 2nd cylinder	754·2	754·4	679·8
Outlet 2nd cylinder . . .	641·3	645·7	—
Spec. heat consumption of turbine for the output at coupling kcal/kWh	2477	2593	2634
Thermal efficiency of turbine referred to output at coupling . . . . %	34·72	33·17	32·65

the changes in the adiabatic heat drop, in the moisture content of exhaust steam and in the losses in the exhaust are taken into account, the results are:—

For test No.		1	2	3	
the spec. steam consumption .	The turbine measured for output at the coupling	3·20	3·14	3·47	kg/kWh
the spec. heat consumption .		2497	2589	2636	kcal/kWh

According to these figures, the thermal efficiency of the turbine under test which, when all is said, is the deciding factor for the degree of steam utilization developed by the set, amounts to 34·72 % when intermediate superheating and condensate heating by extraction are used and referred to the output at the generator coupling; this is a remarkably high figure for a condensing turbine plant.[1] The thermal efficiency drops back to 33·22 %, that is falls by 4·55 %, when the condensate heating by extraction steam is cut out and it drops to 32·63 %—that is by 6·24 % in all — if the intermediate superheating is eliminated.

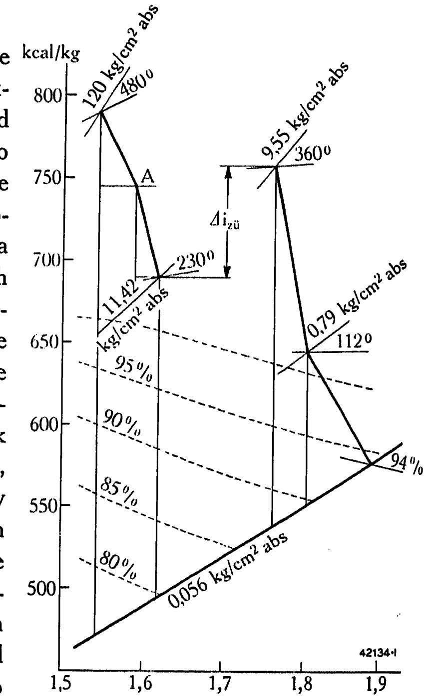

Fig. 4. — J-S diagram.

Thus, the two additional processes are accountable for an appreciable economy in heat.

Further intermediate superheating has the advantage of reducing by about 6 % the moisture content of the exhaust steam.

IV. THE THERMO-DYNAMIC EFFICIENCY.

Fig. 4 illustrates the distribution of the total heat drop between the three cylinders. A considerable fraction — amounting to about 37 % — of the

[1] The Mollier steam tables 6th edition and those of Stodola 6th edition with a reduction of the adiabatic fall of 6·5 kcal/kg for the high-pressure part as a result of the intermediate superheating along with a p. f. = 1 were taken in determining the guaranteed output. This having been taken into account the thermal efficiency of the set in the case of test No. 1 and referred to terminal output amounts to 34·4 %, this after the load fluctuations have been taken account of by a margin of 0·9 %, which figure results from observations during tests.

TABLE III.

Test results in service with and without extraction
(with intermediate superheating).

Test No.		1 with extraction	2 without extraction
Internal output of turbine . . .	kW	26,480	26,952
Here the 1st cylinder is calculated from pressure and temperature[1]	„	9,745	9,642
2nd cylinder calculated from pressure and temperature[1]		10,625	10,220
Total	„	20,370	19,862
Therefore, 3rd cylinder	„	6,110	7,090
1st cylinder:—			
Adiabatic drop referred to condition in nozzle-chamber 1	kcal/kg	136·1	137·0
Adiabatic output	kW	13,280	13,350
Thermo-dynamic efficiency calculated from pressure and temperature	%	74·0	72·9
2nd cylinder:—			
Adiabatic drop	kcal/kg	127·8	123·3
Adiabatic output	kW	12,470	12,020
Thermo-dynamic efficiency calculated from pressure and temperature	%	88·3	88·2
3rd cylinder:—			
Adiabatic drop	kcal/kg	93·8	98·7
Quantity of steam	kg/h	76,660	83,826
Adiabatic output	kW	8,362	9,618
Thermo-dynamic efficiency referred to internal output	%	73·0	73·7
Thermo-dynamic efficiency of the turbine referred to output at coupling	%	76·4	75·8

[1] Taking sealing-gland losses into account.

TABLE IV.

Results of tests in service with and without intermediate superheating
(without extraction).

Test No.		2 with intermediate superheating	3 without intermediate superheating
Internal output of the turbine	kW	26,952	24,252
Heat drop utilized in turbine corresp. to the internal output	kcal/kg	276·5	251·0
Of this drop, the 1st cylinder utilized	kcal/kg	99·9	108·2
Therefore, the 2nd and 3rd cylinders utilized	kcal/kg	176·6	142·8
Heat content of steam in exhaust branches, corresp. to heat drop utilized	kcal/kg	577·8	537·0
Humidity of exhaust steam .	%	5·9	12·8
1st cylinder:—			
Adiabatic heat drop referred to conditions in nozzle chamber 1:—	kcal/kg	137·0	148·1
Thermo-dynamic efficiency calculated from pressure and temperature:—	%	72·9	73·0
2nd and 3rd cylinders:—			
Adiabatic heat drop . . .	kcal/kg	218·9	183·3
Thermo-dynamic efficiency corresp. to drop utilized	%	80·7	77·9
Adiabatic heat drop total .	kcal/kg	355·9	331·4
Steam consumption with adiab. expansion	kg/kWh	2·417	2·595
Thermo-dynamic efficiency of turbine referred to output at coupling	%	76·5	74·4

total drop is utilized in the first cylinder. The thermo-dynamic conditions of the turbine in this cylinder are of especial interest as, apart from the Curtis wheel placed in front, the Brown Boveri design tested here works with reaction blading, as well. The relation of the internal heat drop as determined by temperature and pressure measurements, and the adiabatic drop allows of determining the internal efficiency. The figure of 73 % was obtained for the first casing and in all three tests (Tables III and IV). Here, about half the high-pressure fall is used up in the Curtis wheel.

The thermo-dynamic efficiency of the Curtis wheel for all tests was between 60 and 62 %. Here, there is a certain element of uncertainty, as only temperature measurements recorded at one point behind the Curtis wheel in the chamber can be referred to. The reaction part of the high-pressure cylinder, with a Parsons' number of about 3250 works to an internal efficiency of 80 %.

In the case of the second cylinder, the conditions for good utilization of the steam are improved. The internal efficiency amounts to about 88 % (Table III) as referred to pressure and temperature and for tests with intermediate superheating, this with a Parsons' number of 3450.

For the low-pressure cylinder, the internal efficiency was determined on the basis of the internal output, on account of the moisture contained in the exhaust steam. This output is calculated from the difference between the total internal output of the turbine and the sum of the internal outputs of the first and intermediate cylinders (Table 3). According to this, the internal efficiency of the low-pressure cylinder, when testing with intermediate superheating, amounts to about 73·5 %.

In test No. 3 without intermediate superheating (Table IV) no division of measurement results was made between the intermediate and the low-pressure cylinder, as no degree of superheat of the steam after the second cylinder was detected and, therefore, the steam

condition could not be determined. However, in order to allow of comparing the thermo-dynamic conditions of the turbine when operating with or without intermediate superheating, the results of test 2 were calculated in the same way as those of test 3 and are given in Table IV. When intermediate superheating is cut out, the efficiency of the second and third cylinders fall from 80·7 % to 77·9 %. Without intermediate superheating the water content of the exhaust steam is 12·8 %.

A thermo-dynamic efficiency of about 76 % was determined for the whole turbine operating with intermediate superheating and referred to the power delivered at coupling (Table III). In considering this value, it should be remembered that, here, the adiabatic drop is the sum of the three partial drops in the high, intermediate and low-pressure cylinders. Now, the adiabatic total output is the greater, and the resulting thermo-dynamic efficiency of the turbine the smaller, the more the total heat drop is subdivided. This is seen by a comparison of the efficiency given for the whole turbine, by test 2 in Table III with the figures given in Table IV for the same tests; the values of Table III are somewhat lower than those of Table IV because, in the latter case, the total drop is only subdivided into two partial drops as compared to three in Table III.

Usually, the overall efficiency of a purely condensing turbine is referred to the total adiabatic heat drop from live steam conditions down to vacuum. This is not possible, in the present case, because of the intermediate superheating. If the heat regained in the high-pressure stage owing to the non-adiabatic expansion is taken into account and if the intermediate and low-pressure stage are taken in one, an overall efficiency of the turbine of 80 %, referred to coupling output is reached.

When considering thermal and thermo-dynamic efficiency figures reached, it should be remembered that the turbine ran under partial load. One nozzle valve was completely closed and another throttled. It can be presumed that better figures would have been reached if the tests had been made at higher turbine loads.

The works management took over the machine set tested on the basis of the said test results and in recognition of the proved reliability of the machinery.

The tests carried out are specially remarkable as they give numeral proof of the economic advantages of intermediate superheating and feed-water heating by means of extracted steam.

(MS 954) *Prof. E. Josse,* *(Mo.)*
Privy Councillor and Dr. in Engineering.

THE ELECTRIC EQUIPMENT OF THE NEW ROUGHING MILL BELONGING TO THE L. VON ROLL IRON WORKS IN GERLAFINGEN (SWITZERLAND).

I. GENERAL NOTES.

THE L. von Roll Iron Works in Gerlafingen started up a new roughing mill, in the spring of 1934. This mill was built after most thorough investigations into the needs of the plant had been made, the main object aimed at being the design of a rolling mill which would satisfy a very diversified field of utilization. Fig. 1 shows the general layout of the plant. The new rolling mill covers an area of about 160×50 m and comprises two longitudinal and two transversal halls. The firing plant is composed of a pusher-type furnace, fired by producer gas, for an output of 100 t in eight hours and working with a draught temperature of 1200° C. The waste heat is utilized in a tube-type recuperator, for preheating the air used in combustion. The ingots at white heat are drawn on to a roller train by a spill and this roller train conveys them to the blooming mill. The latter consists of a patented type of stand having three rollers which are electrically adjustable, lifting tables, tilting devices and guides and can handle ingots of up to 1200 kg each. The blooming mill delivers partly finished products of square or rectangular section which pass to the next mills in the process. It is also used to make half-finished products for the other intermediate mills and finishing mills, sheet-steel mills and smithy. At a distance of 23 m, there are hot shears to handle rectangular sections up to 165 mm a side; these shears cut off the material which has passed through the blooming mill to the requisite lengths and cuts off bad ends. After it, come two finishing mills one being a heavy mill with two stands with 650 mm rollers and one with four stands and 450 mm rollers. This latter one can be made over into a strip mill for strips up to 300 mm in width. Taking into consideration the great diversity of sections turned out by the L. v. Roll Iron Works, it was essential to provide for quick substitution of rollers and,

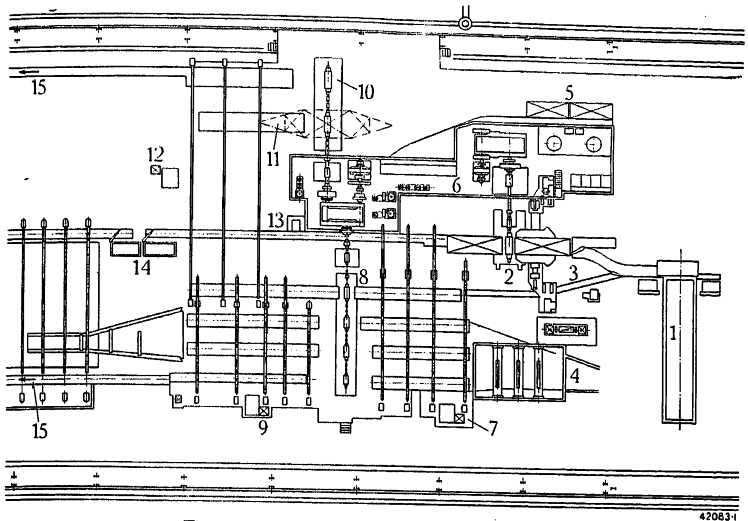

Fig. 1. — Layout of the new roughing mill.

1. Pusher furnace.
2. 650-mm blooming mill.
3. Feed roller gear of the 450-mm finishing mill.
4. Underground passage-way.
5. Dismantling opening for the transformers.
6. Motor house.
7. Puller drive.
8. 450-mm finishing mill.
9. Puller drive.
10. 650-mm finishing mill.
11. Travelling overhead tilting device.
12. Puller drive.
13. Billet shears.
14. Charging trough.
15. To the cooling bed.

to this end, the stands were made to be changed. While the rolling process is going on, spare stands are built up to take the next section to be rolled, this work being done in a assembly pit; these stands are then placed in line, when required. It takes 20 minutes only, to change a stand. The finished products are conveyed away from the mill to a semi-automatic cooling bed by means of roller trains. From the cooling bed, the material is conveyed to the roller train of the 500-t shears and after being cut to lengths it is weighed and controlled. For material which is to be cut when hot, there are hot saws placed one behind the 650-mm mill and one behind the 450-mm mill. Straightening machines and straightening presses for cold rectifying, strip-iron winders, etc. complete the equipment. The whole forms a very up-to-date plant and, as regards production and quality of product, is of the highest class.

II. THE MAIN DRIVES.

The electric drives of the new roughing mill are composed of main drives and auxiliary drives; the main drives comprise the rolling-mill motors proper with the accessories belonging thereto. The layout of these main drives is carried out in accordance with the general diagram of connections shown in Fig. 2.

It may be of interest to give the reasons which dictated the choice of current and connections, in this plant. The main point in plants of this kind is the kind of current which is available and which, in the present case, was A. C. 3000 V, three-phase, 50 cycles. A comparison has then to be made between this current system and its particular characteristics and the service conditions to be satisfied by the rolling-mill motors; the latter being, of course, essentially dependent on the rolling programme worked to in the mill. In the present case, speed regulation over a wide range for both rolling-mill motors was called for, namely 1 to 2 for the blooming mill and 1 to 2·5 in the finishing mill. If only a single rolling-mill motor had been used, a three-phase motor with a regulating set of Brown Boveri-Scherbius type would have been the most advantageous solution, alternatively, perhaps, with a regulating set of Krämer type and it will be of interest to mention here that one of the

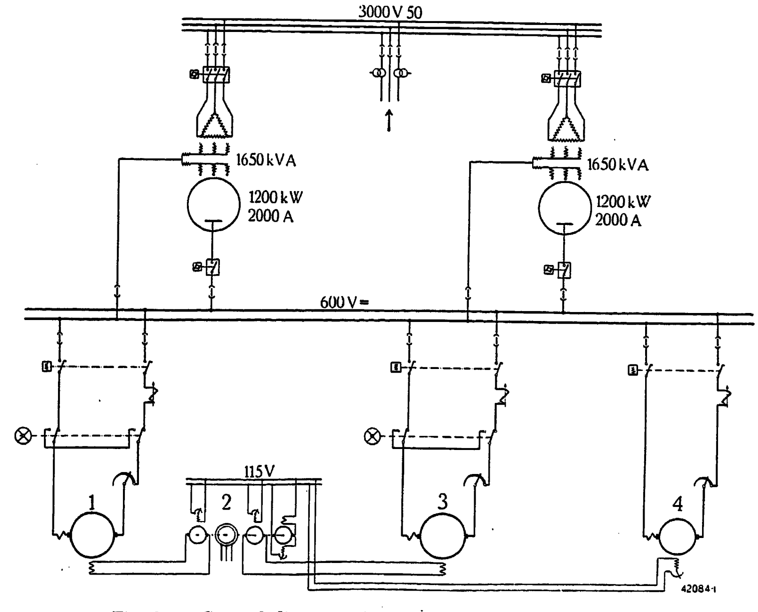

Fig. 2. — General diagram of connections of the main drives.

1. Blooming-mill motor, 885 kW, 600 to 1000 r. p. m.
2. Exciter set.
3. Finishing-mill motor, 1100 kW, 340 to 850 r. p. m.
4. Vertical roller stand motor, 110 kW, 300—1000 r. p. m.

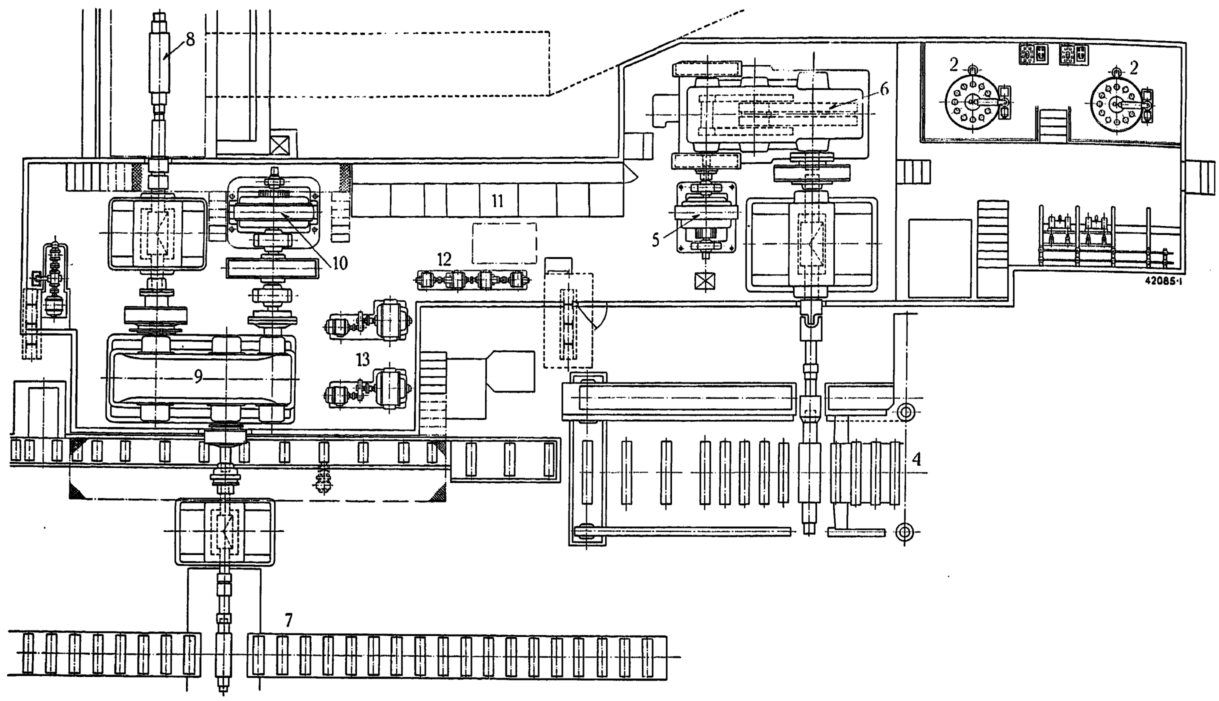

Fig. 3a. — Layout of the motor house of the new roughing mill.

1. Mutator transformers.
2. Mutators.
3. Ventilating plant.
4. 650-mm blooming mill.
5. Driving motor of blooming mill.
6. Reduction gear of blooming mill.
7. 450-mm finishing mill.
8. 650-mm finishing mill.
9. Reduction gear of finishing mills.
10. Driving motor of finishing mills.
11. Main switchboard.
12. Exciter set.
13. Frequency converting set.

first Brown Boveri-Scherbius regulating sets ever delivered has been working, since 1910, in the Gerlafingen works. As, however, not one but two motors, and a third one of 110 kW for the vertical roller-stand drive, had to be considered, it was out of the question to use either of the above mentioned regulating methods, and the most-simple and economical solution was the drive by D. C. shunt motors.

There was, however, no D. C. supply sufficiently powerful available so that the D. C. motors of the new roughing mill had to be supplied separately from the other motors in the plant. To do this, two solutions were practicable:— current supply through rotary converters (motor-generator sets or single-armature rotary converters) or current supply from mutators. The latter solution has the advantage of being more economical, as the efficiency of the mutator is about 2 to 3 % higher at full load and, being thoroughly reliable, it requires little attendance. For these reasons, a mutator plant was purchased.

As Fig. 2 shows, the power supply is through a single incoming line to the transformer station. This incoming line is brought into the cellar-floor level of the motor house shown in Fig. 3. The apparatus for the incoming line and for the two outgoing lines are mounted on a three-panel switchboard in the cellar chamber. The two outgoing lines have each a three-pole, oil circuit breaker which can be worked by motor remote control from the main switchboard. These lines are laid to the mutator transformers each of 1650 kVA continuous rating. The latter are also lodged on the cellar floor level, as shown in

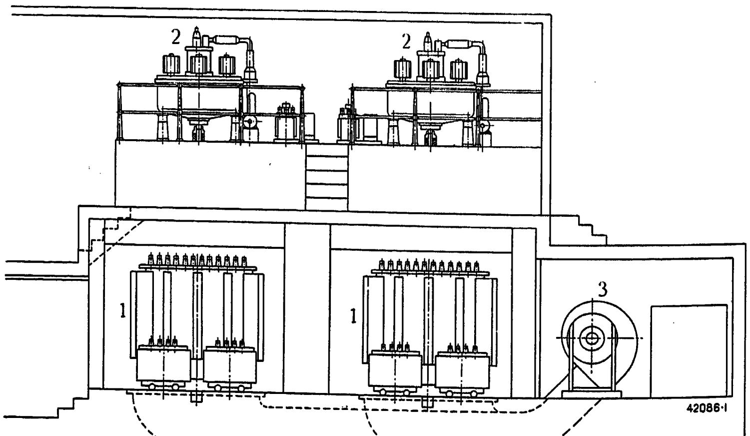

Fig. 3b. — Section through mutator plant.

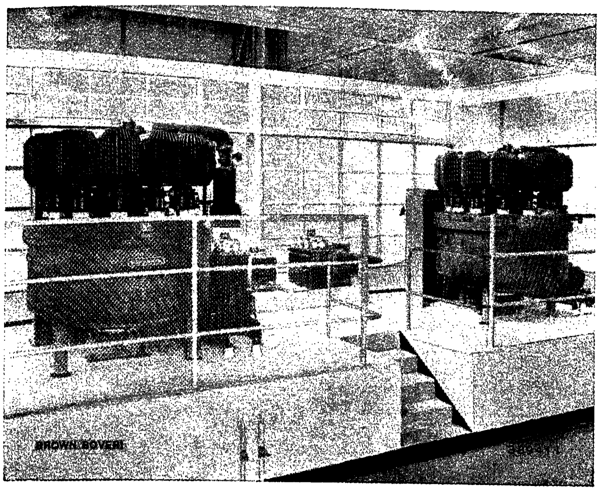

Fig. 4. — Two mutators each of 1200 kW, 600 V, for supplying rolling-mill motors.

Fig. 3; they are designed with radiators for natural cooling of the oil, the draught being reinforced, if required, by motor-driven fans placed in a neighbouring chamber, which also contains two other fans for artificial cooling of the motor house. The two mutators are lodged directly over the mutator transformers, these are units of 1200 kW continuous rating (Fig. 4). The ignition set and vacuum pumps are visible in the illustration beside the two mutators. After removing the roof of the motor house, the mutators

	Blooming mill	Finishing mill
Continuous rating .	885 kW	885—1100 kW
Momentary overloading . .	100 %	100 %
Speed variation at full load . . .	600—1200 r.p.m.	340—850 r.p.m.

are accessible and can be raised by the rolling-mill crane, above them. They supply D.C. 600 V bus-bars through D.C. high-speed circuit breakers lodged on the cellar floor level. The two rolling-mill motors and the motor for the vertical rollers are connected up to the said bus-bars. There is a special excitation set to supply the excitation of all the motors. The two rolling-mill motors are built for the conditions given in the above table.

Both motors are built with compensating winding and built-on centrifugal switch in order to prevent them running away if their excitation circuit is interrupted. The chief factors taken into account in the electrical and mechanical design of these motors are the numerous load peaks they have to overcome, which go as high as a 100 % overload and, also, the high peripheric speed of the rotor, resulting from the wide range of speed regulation. The housing is of cast steel in two parts; it has two stout feet and is bolted down to a cast-iron bedplate which is let into and anchored to a concrete bed. The main poles are laminated while the interpoles are of forged iron; these poles are secured by stout steel screws to the housing. Apart from the windings on the main poles and interpoles, there is a compensating winding placed on the stator which improves commutation, under the severe load peaks and high speed conditions met with.

The rotor laminations are of 0·5 mm thickness (losses 3 W/kg); they carry the rotor winding. There are pressure rings of cast steel to press the laminations together and the rotor coil heads rest on these. The active rotor body is carried on a cast-steel spider and maintained in position by keys and bolts. The rotor star is pressed and keyed on to a heavy shaft of S. M. steel of about 55 kg/mm^2 tensile strength. The bearings carrying this shaft are of the journal type of thoroughly reliable design, each bearing having two lubricating rings. The tensile strength of the cast-steel material used is about 45 kg/mm^2. Apart from the rotor spider, the shaft carries the commutator bushing which is also of cast steel and on which the copper segments are rigidly held by conic steel rings. The commutator segments are of the highest-grade hard-drawn electrolytic copper. The stout brush carriers are of cast iron secured at their outside ends by a distancing ring to prevent vibration. These

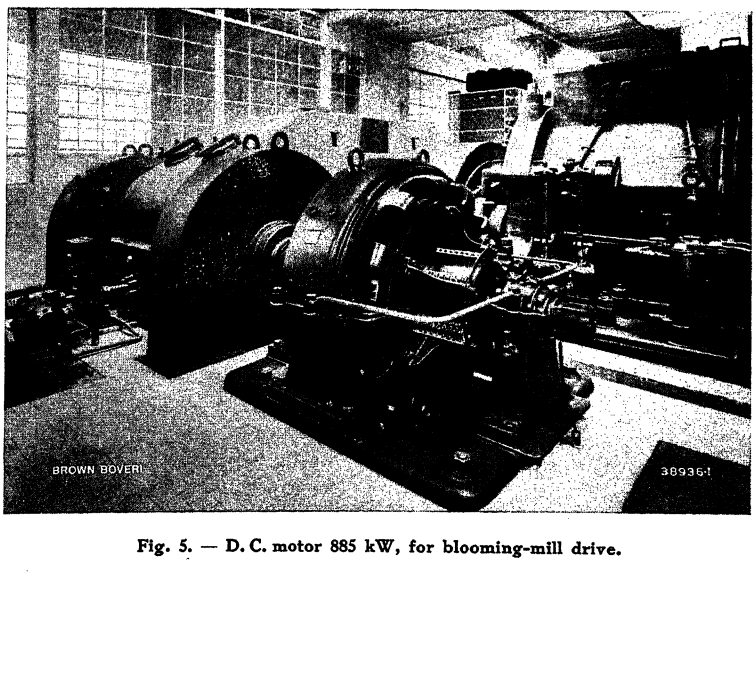

Fig. 5. — D.C. motor 885 kW, for blooming-mill drive.

brush carriers are secured by screws to a cast-iron brush rocker in two parts which serves, at the same time, as a shield. A cast-iron shield in two parts protect the windings on the driving side and serves for guiding the cooling air.

A fan under the shield cools the machine by drawing in cold air on the driving side and by blowing out the hot air on the commutator side through the apertures in the shield. As mentioned before, there is also a central ventilating plant in the cellar of the motor house which, if required, can lead cold air directly to the pits just below the main motors. All windings carrying the main current are insulated by high-grade mica while the copper of the excitation windings is cotton insulated. All insulations are carefully impregnated.

The two motors drive the rolling mills through reduction gears. In the case of the blooming mill (Fig. 5), the flywheels to compensate the load peaks are mounted on the fast-running shaft on both sides of the pinion. In the case of finishing mill, the flywheel is placed between the motor and the reduction gear (Fig. 6).

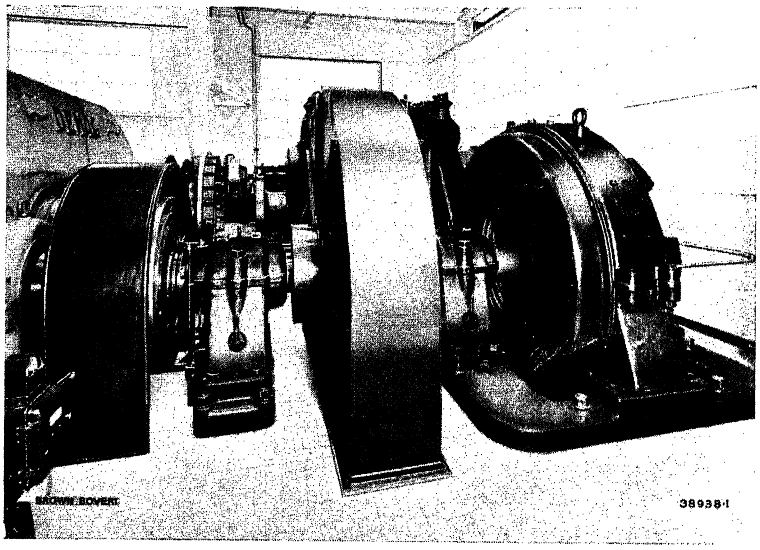

Fig. 6. — D. C. motor 885–1100 kW for finishing-mill drive.

The motor shaft of the blooming mill is coupled up by means of a very flexible flat-spring, Babba-Klus type coupling combined with the flywheel. The outer diameter of this coupling is 740 mm and it transmits a torque amounting to 2900 mkg. Another Babba-Klus coupling is used to connect the slow-running shaft of the reduction gear to the pinion frame of the blooming mill. This has to transmit a peak torque of 86,000 up to 107,000 mkg (at 40 and 80 r. p. m. respectively). It is combined with a breaker also termed mechanical fuse the two safety bolts of which should rupture at 130,000 mkg. There is an electro-magnetic friction coupling of the Klus design between the flywheel and reduction gear on the drive of the finishing mill. This coupling can transmit a torque delivered by the flywheel of 1100 mkg with an external diameter of as little as 1460 mm, which torque corresponds to 3850 kW at 340 r. p. m. and 9600 kW at 850 r. p. m. The D. C. consumption for this coupling is only about 5·2 A, at the moment of engaging, and only 4·2 A when once engaged, at 80 to 100 V. The slow-running shafts of the reduction gear of the finishing mill are also coupled to the two pinion frames through Babba-Klus couplings. The coupling of the 450-mm mill is 1270 mm in diameter and its highest admissible torque is 47,000 mkg at 80—120 r. p. m. It is disengaged by handwheel. The coupling of the 650-mm finishing mill has a diameter of 1920 mm and can also be disengaged; its highest admissible torque is 75,000 mkg at 50 to 125 r. p. m. All these couplings have given excellent results in practice and brought about efficient damping down of load peaks, which, obviously, is favourable to the length of life of the whole plant.

Fig. 7 shows the connections of the rolling-mill motor plant. These connections are, fundamentally, the same for both motors, with the exception, however, that the motor of both the finishing mills can be reversed which is not the case for the blooming-mill motor. This reversing of sense of rotation is necessary as the two finishing mills, driven by the same rolling-mill motor, revolve in counter-sense with regard to the motor. Both motors are connected to the 600-V bus-bars through disconnecting switches. The two-pole automatic switch is equipped with remote control by electro-magnet, over-current trip on one pole and low-voltage trip. It is used for switching the motor in and out and is so dimensioned as to be able to stand the load put on it in case of short circuit. There is a braking change-over switch which allows of braking down the motor quickly in an emergency; the motor then runs as a generator, as it slows down under the flywheel effect of the masses in rotation.

Both rolling-mill motors are excited from a separate converter set, one D. C. generator delivering the main

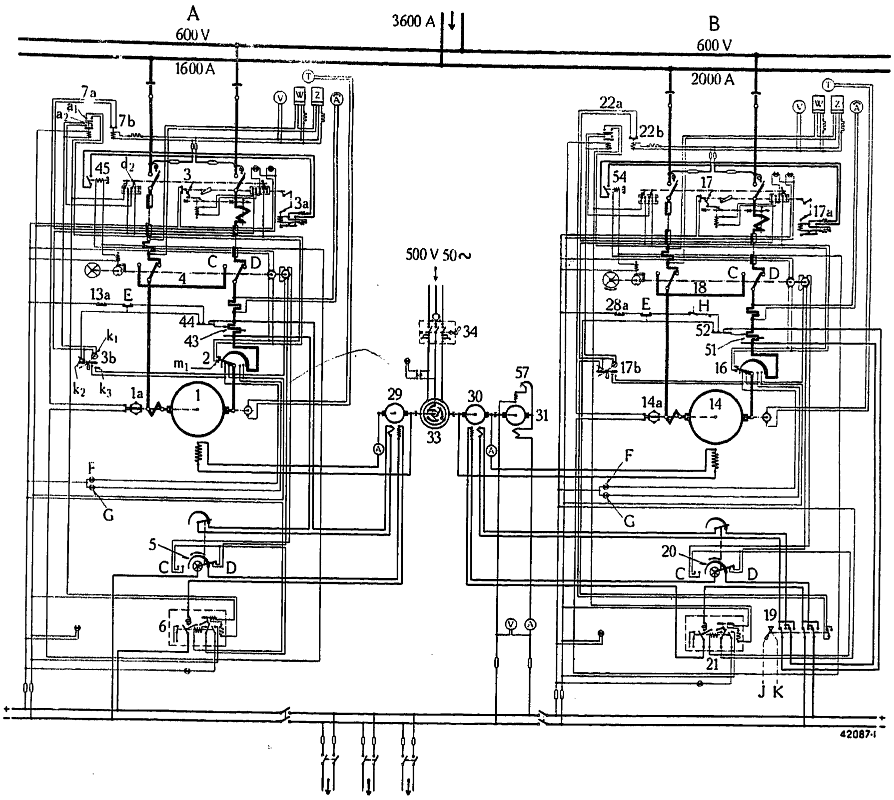

Fig. 7. — Diagram of connections of the rolling-mill motor plant.

1., 14. D. C. rolling-mill motor
- 1. 885 kW, 600—1200 r. p. m., 600 V.
- 14. 885—1100 kW, 340—850 r. p. m., 600 V.

1a., 14a. Centrifugal switch.
2., 16. Starter.
3., 17. Main circuit breaker.
3a., 17a. Electro-magnetic drive.
3b., 17b. Contact maker.
4., 18. Two-pole braking change-over switch with blocking electro-magnet.
19. Five-pole change-over switch for reversing.
5., 20. Field rheostat with compounding resistance.
6., 21. Field switch with switching-in coil and low-voltage electro-magnetic trip.
7a., 22a. D. C. relay to prevent repeated reclosings.
7b., 22b. Low-voltage tripping relay for main 600-V circuit.
13a., 28a. Emergency switch for mounting on rolling-mill stand.
29., 30. D. C. exciter.
31. D. C. exciter for main excitation.
33. Three-phase induction motor with centrifugal starter.
43., 51. Shunt.
44., 52. Single-pole, over-current relay with thermal release.
45., 54. Single-pole D. C. closing contactor.
57. Field rheostat of main excitation.
34. Switchbox with over-current release and ammeter.
A. Blooming-mill motor, 885 kW.
B. Finishing-mill motor, 1100 kW.
C. Braking.
D. Working.
E. Oil-pressure relay on the heavy-duty reduction gear.
F. Starter:— initial position.
G. Starter:— end position.
H. Auxiliary contact on switchbox of the oil-pump motor of pinion frame.
I. 450-mm finishing mill.
K. 650-mm finishing mill.

excitation for all the machines while each of the two rolling-mill motors has its own exciter, which is excited from the main excitation bus. These exciters have a compound winding supplied by a shunt on the main motor leads and which works so that, when the rolling-mill motors take more current, the excitation is increased and the speed of the motors drops. In order to keep approximately constant the amount of compounding applied at the different motor speeds which are within the range of speed variation of the said motors, there is a rheostat inserted in the shunt field actuated along with the other rheostat for varying the speed of the motor. The excitation circuit is closed by the field switch and, at the same moment, the main circuit breaker is closed. The shunt also supplies an over-current relay with thermal release which acts under continuous overloading of the motor but not in case of a short circuit occurring.

All service conditions are signalled by the lighting up of pilot lamps lodged behind transparent panes carrying the requisite inscriptions, thus:— closing of main excitation, both the end-travel positions of starter, position of automatic switch and of the field switch. Each set has its tachometer, voltmeter, ammeter, recording wattmeter and kWh meter.

In order to simplify as far as possible the attendance of the rolling-mill motors and to eliminate service mistakes there are a number of interlocks provided. The designations in the following explanation refer to the 885-kW motor of Fig. 7. First the excitation set is started up and the main excitation switch closed. The signal lamps light up immediately and, if the apparatuses are in proper position, they indicate:— "Main excitation closed", "Main switch open", "Starter in starting position". As soon as the oil-pressure relay on the main reduction gear closes its contact (which occurs only when the oil pressure generated by an auxiliary pump has attained the requisite value) and thus signals that the said

reduction gear can be started, relay 7a is closed through contact k_2 of the contact maker 3b; this relay maintains itself closed through its contact a_2 and contact d_2 on the main switch, which is still open. It also closes the circuit of the low-voltage coil of the field switch 6 through contact a_1 and contact 2 m_1 (closed when the starter is in its primary position) which coil is connected up in ordinary service through a contact on the closed main circuit breaker. Another way of connecting up this low-voltage coil is over braking change-over switch 4 when it is in the "braking" position. The low-voltage coil of the field switch 6 now closes a contact and prepares the closing of the main circuit breaker 3. If, now, the contact maker 3b is rotated clockwise, its contact k_3 is closed and also the circuit of the closing coil of the field switch 6 which, now, in turn, closes the excitation closing switch and the closing contactor 45. This closing operation can only take place if the starter is in its primary position and the field rheostat in the position corresponding to the working or to the braking position of the braking change-over switch. The switching-in contactor 45 can only be closed when the braking change-over switch is in the "working" position. If it is in the braking position, it is true that the excitation is closed but the main switch remains open. The switching-in contactor 45 now closes the closing magnet 3a of the main circuit breaker 3, which also closes while, at the same time, its low-voltage trip circuit is also closed.

It is, of course, possible that main circuit breaker 3 immediately trips again, owing to an existing short circuit. In this case reclosing without a pause must be prevented. Relay 7a performs this duty. This relay which was closed by contact k_1 on the contact maker 3b maintains itself closed through the closed contact 3 d_2 on the open main circuit breaker. If the contact maker 3b is rotated into the closing position, its contact k_1 is opened. When the main circuit breaker is closed, contact 3 d_2 also opens, so that relay 7a must also fall. If, now, the main circuit breaker opens again, a reclosing can only occur when contact maker 3b has, first, been rotated back into its medium position and the breaker tripping which has occured has been signalled back. As the diagram of connections shows, there are a number of contacts in the circuit of the low-voltage coil of the main circuit breaker 3 all of which can cause the motor to be cut out, namely:— emergency switch, oil-pressure relay on the main reduction gear, thermal over-current relay as over-load protection, contact maker 3b, low-voltage relay on 600-V side and centrifugal switch.

The interlocks include only the most essential operations and assure starting up and running in perfect conditions. To start the motor, once the one or other of the mutator sets has been switched in, all that is necessary is to close the main excitation circuit and then the contact maker of the main circuit breaker and, after that to move the starter. All other processes are automatic and require no intervention of operators. After starting up is completed, the motor speed can be regulated by the field rheostat. Experience proved that starting was very easy and quick, so that the motors can be stopped in order to save power consumption even during short interruptions of mill service. The complete switchgear for the motors and mutators is lodged in a switchboard placed in the motor house itself (Fig. 8). As shown, the apparatus for each motor takes up two panels, the apparatus for the 110-kW motor of the vertical roller stand being placed in the panel of the motor of the finishing mill, 1100 kW. There is a special panel between those of the two motors and which is for the excitation set, which is also visible in the illustration. Apart from the indicating instruments for excitation voltage and current, this panel contains the excitation switches to the various motors.

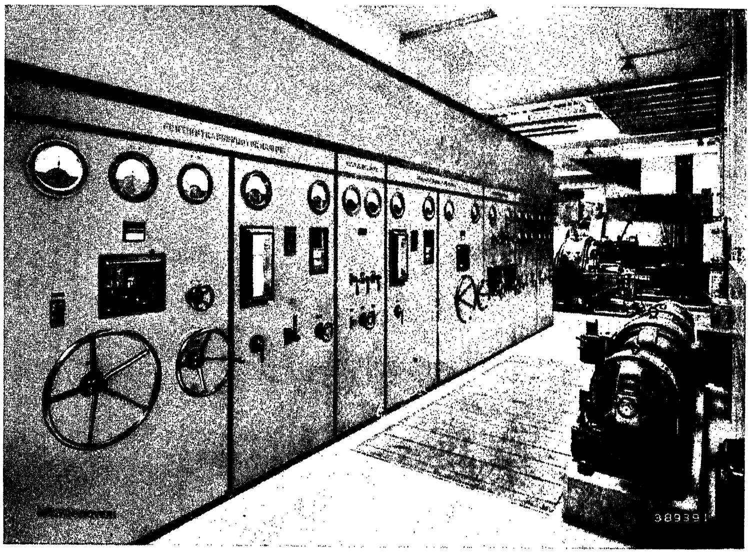

Fig. 8. — Main switchboard for rolling-mill motors and mutators.

With the exception of the main circuit breaker, all apparatus including the starters with their resistances are mounted in this switchboard. The switchboard has a gangway at the back for erection and in which the necessary cables are laid.

III. THE AUXILIARY DRIVES OF THE ROLLING MILL.

It must be stressed here that the so-called auxiliary drives of rolling mills, although they only fulfil secondary functions, have a very great if not preponderant influence on the successful operation of the mill. The mill production depends on them, to a great extent; they also determine the number of men per shift. The new roughing mill of the L. v. Roll Iron Works in Gerlafingen is mechanically operated in nearly every detail and represents the last word in rolling-mill design.

The demands made on the auxiliary drives of rolling mills are very diversified. Attendance requirements must be simple and the plant designed so that it can be looked after by unskilled labour. The motors and apparatus must be rugged and able to stand up to frequent switching operations. As the motors are greatly exposed to dust and to damp through drip and spray water, it is usual to employ totally-enclosed designs, only. All the motors, in the present case, are of the A. C. three-phase, 500-V type, with the exception of those units to drive the Sack-design of rollers and which will be described further on.

1. *The motors.*

In the case of the motors driving auxiliaries, a distinction must be made between those for continuous and those for intermittent service. It is assumed, here, that the design of standard motors which are not totally enclosed, especially that of drip-proof motors, some of which are used in this mill, is so well known already that it need not be gone into, here, only totally-enclosed types of motors being described.

All the totally-enclosed motors for continuous ratings are built with external cooling, to-day. Fig. 9 shows a three-phase, slip-ring motor, 300 kW at 1000 r. p. m. There are two distinct air circuits in this motor:— one is inside the casing and one outside. A fan is mounted on the driving side (AS) which draws in air on that side and blows it over the longitudinal cooling ribs on the outside of the stator housing, towards the other side. The essential problem in this motor design is to bring about as complete transmission as possible of the heat losses inside the machine to the stator housing which, as said before, is efficiently cooled by the external fan acting on its cooling ribs. For this reason there is no air gap left between the external periphery of the stator laminations and the inside of the stator housing, in order that the heat due to losses may be transmitted by direct contact to the stator housing. The rotor is specially cooled by a fan on the shaft which drives air through it. The bearing shield on the driving side has a large number of surfaces on its outside, over which cooling air passes, so that the heat driven out from the interior of the motor is efficiently cooled by contact with its interior surface. All these totally enclosed motors have special insulation treated with special impregnation against damp, acids and corrosive vapours, further the housing is treated with a rust-proof coating. These motors have roller bearings. Connections to the current-supply system is through compound-filled cable end boxes.

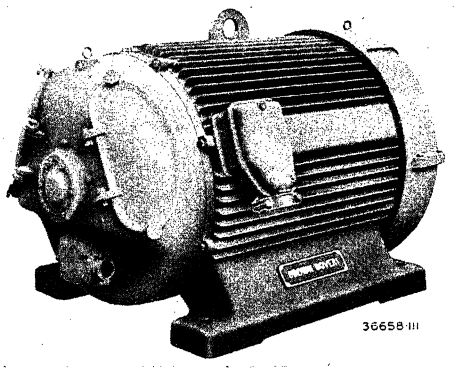

Fig. 9. — Totally-enclosed three-phase motor with external cooling, Type MSUe, 300 kW at 1000 r. p. m.

Fig. 10 shows the design of a totally-enclosed motor for intermittent and heavy reversible service, such as is used to drive the ingot-pushing device. In the new roughing mill of the L. v. Roll Iron Works,

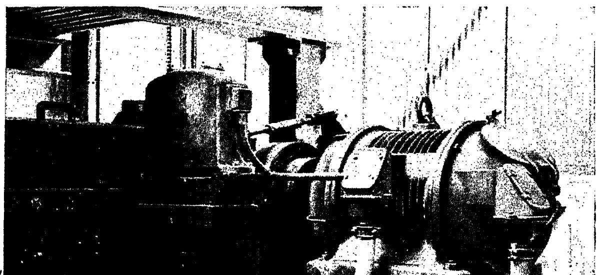

Fig. 10. — Totally-enclosed three-phase motor type MH, to drive an ingot pusher.

Gerlafingen, there are about 20 motors of this MH type for outputs ranging from 15 to 38 kW, of the 10-pole design. They are totally enclosed but, contrary to the motors for continuous rating, have no external cooling fan. For this reason, the housing has concentric cooling ribs instead of longitudinal ones and this adds to the rigidity of the housing. Here, also, the outside periphery of the stator laminations

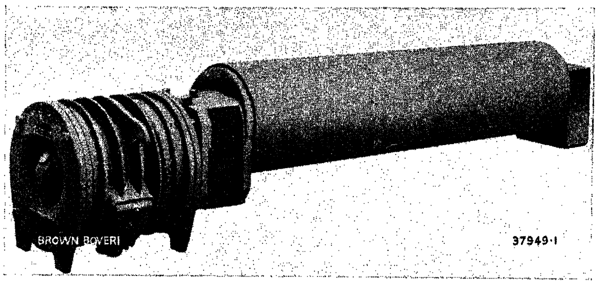

Fig. 11. — Roller of Demag design with built-on Brown Boveri motor.

comes right up against the inside of the stator housing, in order to activate heat radiation. The air inside the machine is kept in active circulation by a fan. The stator winding is specially insulated and impregnated several times. The rotor is specially designed to have a low flywheel effect. The slip rings have continually applied brushes as control is usually by controller or contactors. The rotor laminations are mounted on a cast-iron spider keyed on to the shaft. The motor has cylindrical roller bearings, at both ends, with grease lubrication. The bearing cover on the driving side is in two parts so as to allow of opening the shield easily without taking away the coupling. The stator and rotor windings are connected up through compound-filled cable-end boxes. The slip rings are made accessible through a hinged port in the bearing shield which is sealed by a felt lining.

These three-phase MH-type motor are used to drive a number of auxiliary devices such as adjusting gears, ingot pushing devices, ingot tilting devices, oscillating or tilting tables, etc.; they are also used to drive the tilting-table rollers of the blooming mill. Formerly, this last duty was generally performed by rollers driven in groups, one motor driving a number of rollers through a common shaft and each roller having its own conical gear. Lately, the tendency is in favour of individual drive for each roller. This has special advantages, among others mechanical imperviousness, adaptability as regards the arrangement of the individual rollers, according to requirements, in curves, for example. There are several designs of rollers for individual drive now on the market.

Two different designs of rollers were used in the new Gerlafingen roughing mill in combination with Brown Boveri motors, namely: — the Demag, Duisburg design with built-in spur-wheel gear drives and the Sack, Düsseldorf design with direct drive of the roller, without a gear. For a given roller diameter fixed for certain reasons, the transmission speed of the rollers is the determining factor in fixing the speed and, therefore, number of poles of the driving motor, the periodicity being constant. The diameters of the rotor of the motor must be kept low so as to restrict its flywheel effect, a necessity when the sense of rotation has to be changed so very frequently. Further limits are set on the external diameter of the motor as it has to be inferior to the external diameter of the roller in order to allow of moving the rolled product transversally on the rollers. The two firms of roller makers just mentioned use different means to attain the results desired.

For the Demag type of electric roller, a three-phase motor is used which is supplied direct from a low-voltage system 500 V, 50 cycles. As it would be impossible, in practice, to build a motor for roller drive having the large number of poles required, this on account of the restricted diameter of the motor, it is necessary to lodge a spur-wheel reduction gear between motor and roller. By this method it has been found possible to use motors rotating at relatively high speeds (6, 8 and 10-pole motors in the present case). Fig. 11 shows an electrically driven roller of this type with its motor, while Fig. 12 shows the

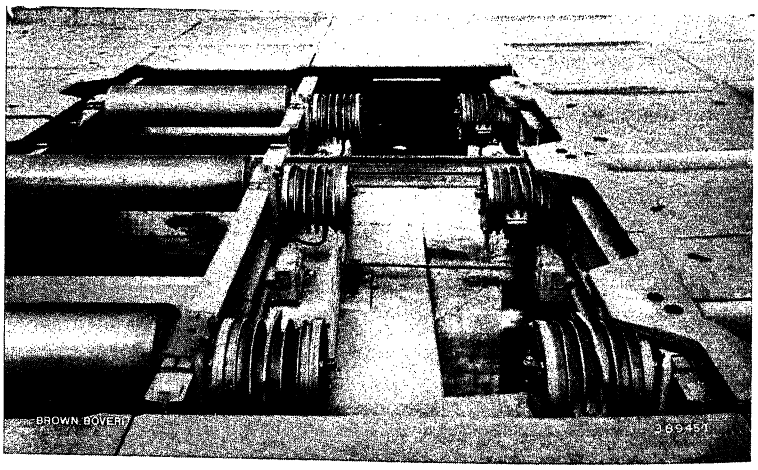

Fig. 12. — The building-in of Demag rollers with Brown Boveri motors built on.

way in which the roller is built in. Mounting and dismantling are very easy operations, carried out by lifting the roller out vertically. The motor is connected up to the main supply system through a flexible cable and a plug contact plugged into a fuse box. In case of a defect it is the simplest matter to disconnect the plug and to go on using the roller as a loose roller.

The Sack type of electric roller dispenses with a reduction gear and has its motor direct-coupled to the roller. In order to adjust the running speeds of roller and motor, a frequency changer set is used which supplies the motors at a lower frequency. In the present case, motors at 50 V and 14 cycles were used. Fig. 13 shows one of these rollers. The motor is coupled to the roller through a Babba-Klus coupling. Fig. 14 shows the standard way of building in rollers of this type. Current is led to the motor in exactly the same way as to the motor of the Demag roller. The two frequency changer sets in this plant used for the Sack rollers are shown in Fig. 15. Each set is composed of a three-phase motor with centrifugal starter, of 27 kW output which drives a synchronous generator through a Klus reduction gear. Both the frequency-changing sets are lodged in the motor house. In order to make the switchgear plant more adaptable to emergencies the different sets of Sack rollers are supplied through two sets of bus-bars, which carry about equal loads. By laying over a lever switch on the main switchboard, the two bus-bar systems can be coupled and the whole plant run from one frequency-changer set, the second acting as spare. Parallel operation of the two frequency-changer sets is not considered.

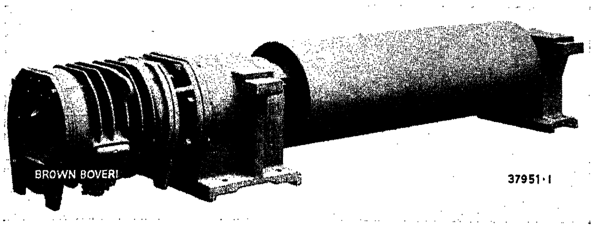

Fig. 13. — Roller of Sack type with built-on Brown Boveri motor.

Fig. 16 shows very clearly the difference between group drive and individual drive of rollers. On the left are shown three Sack-type rollers belonging to the feed rollers to the blooming mill while, on the right, the three-phase motor type MH is seen which drives the rollers of the oscillating table through the reduction gear in the foreground, and through a corresponding number of conical gears.

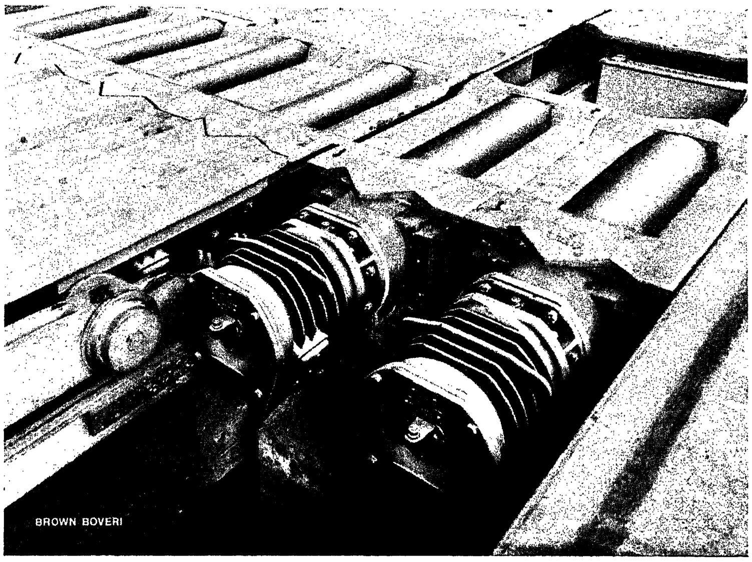

Fig. 14. — The building-in of Sack rollers with Brown Boveri motors built on.

The motors delivered by Brown Boveri for Demag and for Sack rollers are totally enclosed and have no external ventilation at all. The housing has several concentric cooling ribs of which the top part of the middle one is built to form a suspension hook. The stator laminations come up right against the inside of the stator housing. The stator winding is especially impervious to heat, the wires being asbestos insulated and the

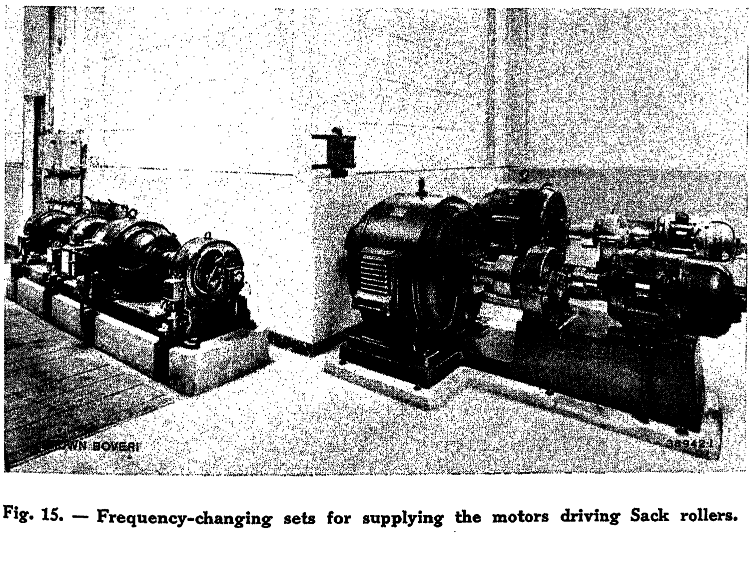
Fig. 15. — Frequency-changing sets for supplying the motors driving Sack rollers.

slots lined with mica while the whole was impregnated several times. This insulation impervious to heat was specially chosen as it happens, even in ordinary service, that a very high surrounding temperature (up to 60° C) may prevail, this near the motors which are close to the pusher furnace. The bearing shields are concentrical to the housing and are bolted to the latter. They carry feet for depositing the motor for mounting and transport. The terminal box is obliquely placed in the lower part of the housing, current is supplied through a plug switch in a fuse box. Tests have proved that perfect protection of these motors even against gripping is possible when the Stotz type of automatic protective trip is used. The rotor is built with a special squirrel-cage winding of copper. The laminations are directly mounted on the shaft in the motors for the Sack rollers, while, in the motors driving the Demag rollers, the rotor body is secured by keys and nuts to the shaft. In the Demag rollers, the shaft carries a steel pinion pressed on and can only be changed as a whole; in the Sack rollers, the shaft end carries a Babba-Klus coupling which connects roller and motor. The motors of the Demag rollers have cylindric roller bearings (stronger ones on driving side) while Radiax ball bearings are used for Sack-roller motors. Grease lubrication is used, in both cases, Mewi-type lubricators being used.

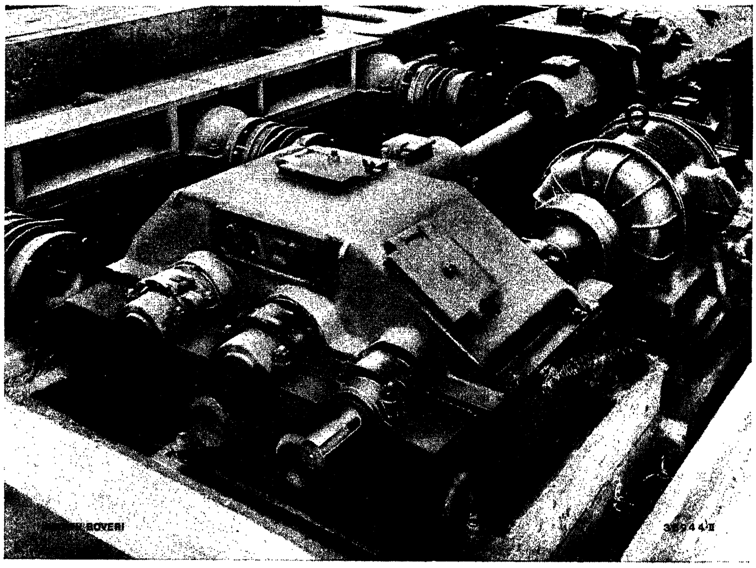

Fig. 16. — Drive of the rollers of the blooming mill.

The calculation of the motors was based on the weights of the product to be moved and on the flywheel effect of the rollers, the torque diagram being drawn up, taking into account the starting times desired. Other factors to be reckoned with were the frequency of switchings and the number of reversals, i. e. counter-braking operations. Fig. 17 shows the main characteristics of a motor of this kind, current and torque in function of speed with motor drive and when braking is applied. It is worthy of note that the biggest torque takes place at starting, in motor service, which is contrary to what occurs with usual motor connections and that this torque goes down as the speed increases. This is a very desirable quality when short starting periods are considered. The switching-in currents do not exceed the usual values for plants of this size while the power factor is also within admissible limits.

2. *The controls.*

These allow the auxiliary drives with the motors driving them to be governed by the operator and they must, therefore, be light as well as handy and must not call for any special care. Apart from the well-known regulation by controllers, used for a number of drives, automatic contactor control has been widely introduced into the present mill. Contrary to controller service, the carrying out of switching operations by automatic contactor control is then no longer in the hands of the operator but is effected automatically. The operator has only got to impart the switching impulse and is relieved of the supervision of the subsequent switching functions.

Control is through so-called master switches, each mounted on a stout gas pipe pedestal. Thanks to their restricted dimensions, they could be grouped in sets on the control gangway and their operation confided to one man. Each master switch has a preliminary and a main contact the reason for which will be explained, later. Fig. 18 shows the control post of the blooming mill which is operated by two men. The master switch was

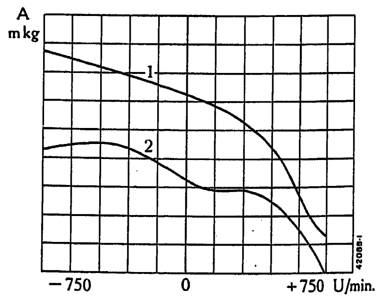

Fig. 17. — Current and torque characteristics of a three-phase motor to drive a roller.
1. Current. 2. Torque.

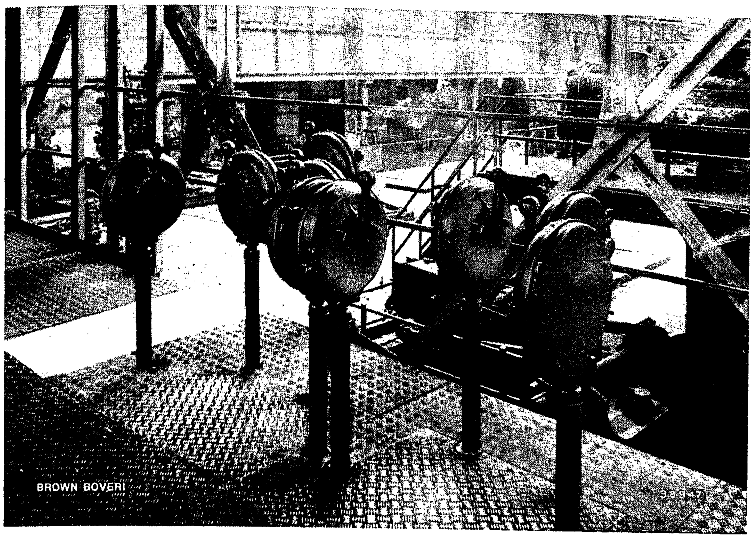

Fig. 18. — Control post and master switches of the blooming mill.

so mounted that the control is of the natural type, by which is meant that the position of the control lever always corresponds to the sense of displacement of the apparatus controlled.

Fig. 19 gives the general diagram of connections of the whole plant. According to the type of driving motor used and the current system employed, the connections differ and they are summarily described herewith. In all the controls there are three heavy-duty fuses built in to act as a protection against short circuits and heavy load peaks. The control voltage is 125 V at 50 cycles, throughout. Each separate control has its own cutting-out device combined with a corresponding automatic trip if the motor supply voltage fails.

The squirrel-cage motors driving the Sack type of rollers are supplied from a double bus-bar system 50 V, 14 cycles. The control is limited to forward and reversing contactors, governed by a master switch. Certain groups of rollers are subdivided, as regards switching, in such a way that a single switching impulse is required to control them but this takes place in such a manner that only a first set of motors is started up at the beginning. By means of automatic time control, a second set is started up, after some seconds and the last set of rollers after a further lapse of a few seconds. This is done so as to avoid overloading the generator of the frequency-changing set by imposing a sudden load peak at starting. "Forward" and "Reverse" contactors are always so interlocked that only one or the other can be closed at the same time.

The motors of the rollers of Demag design are connected up to the standard 500 V, 50 cycles supply. They are also controlled by a "Forward" and by a "Reverse" contactor which are interlocked. Further there is a three-phase series resistance in the stator circuit, which makes possible a reduction of the motor torque at a given voltage or a prolongation of the starting time and, thus, a gradual start under a given torque. This resistance can also be shunted by a special contactor. Control takes place as follows:— when the master switch is on the first step, only the "Forward" or "Reverse" contactor of the stator is actuated and the motor starts with the series resistance inserted. Of course, the second step can be switched over to, immediately, and, if this is done, the series resistance is only in circuit during the passage over the first step.

As already mentioned, each motor of the rollers has its own fuse box. There is no overload protection for the total output, which, obviously, would not operate if separate motors became defective.

The slip-ring motors for reversing rolling-mill service are all equipped with, practically, the same controls. Firstly, the three heavy-load fuses, already mentioned, are on the main-current circuit, then comes a lever-type switch used as disconnecting switch, a thermal relay as protection against overloads and a stator contactor for the forward and one for the reverse control which are mechanically interlocked. The rotor resistances are built into the switchboard, these being controlled by three rotor contactors. The control circuit of each separate control is easily isolated by a disconnecting lever switch and fuses. Control is also by master switches in this case. If these switches are displaced from the middle position on to the preliminary step, only the "Forward" or "Reverse" stator contactor is closed, to begin with and the motor starts with the full rotor resistance inserted. The control of the rotor contactors is only actuated when the master switch is displaced to the second step. As a stator contactor closes, its built-on acceleration relay is freed and its winding only remaining under the influence of the rotor current. If the rotor current falls, the armature of the acceleration relay falls and its contact switches in the first rotor contactor which short-circuits the first part of the rotor resistance. This brings about a new current peak and the same sequence of phenomena is repeated

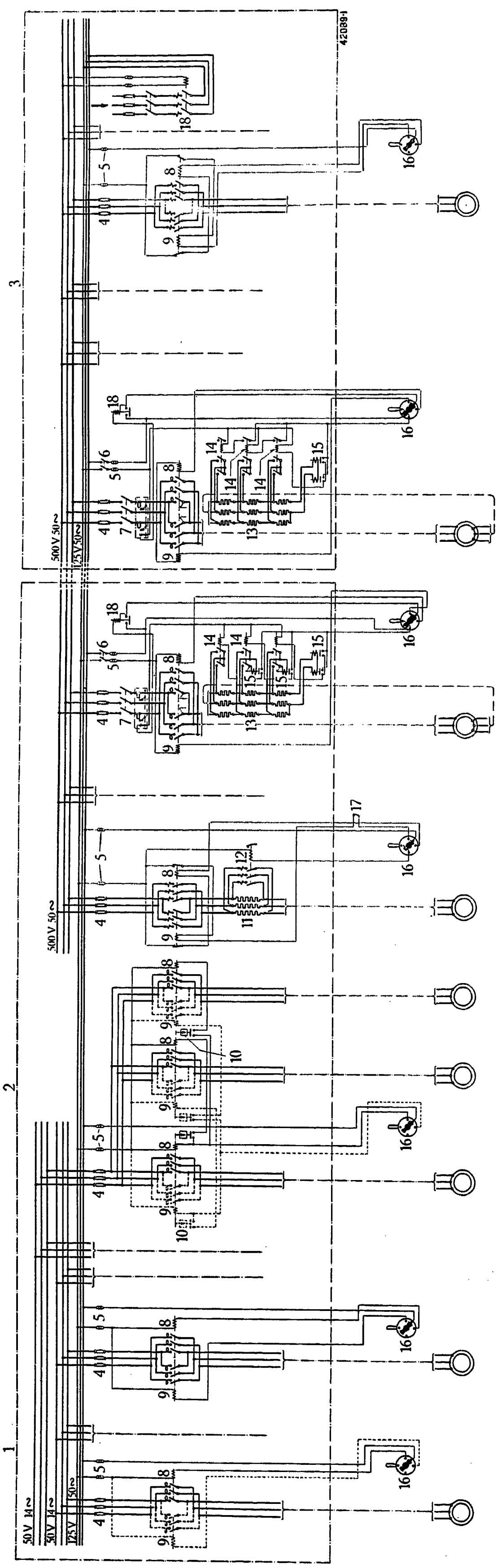

Fig. 19. — Diagram of connections of the auxiliary services.

1. Control gangway A.
2. Switchboard 1.
3. Switchboard 2.
4. Main fuse.
5. Control fuse.
6. Switch for control current.
7. Switch for main current.
8. Main contactor "Forward".
9. Main contactor "Reverse".
10. Time relay.
11. Series resistance.
12. Shunting contactor.
13. Starting resistance.
14. Rotor contactor.
15. Acceleration relay.
16. Master switch.
17. End switch.
18. Low-voltage relay.

until the second and third rotor contactors are closed and the whole rotor resistance is short-circuited. In certain controls, which have to be operated very frequently, and, therefore, must have very short closing times—for example roll-adjusting screws—the acceleration relays are left out and replaced by ordinary auxiliary contacts which bring about consecutive closing of the rotor contactors. When the lever of the master switch is reversed and brought back to its original position the stator is cut out again as well as the rotor contactors. The connections are such that the same control can be exercised by two master switches, in which case one of the master switches is given a leading part the other master switch having to give precedence to it.

There is a low-voltage relay in the control current circuit of each control and the current to the master switch is made to pass through its contact. The connections are such that, if a voltage failure occurs, this relay can only be switched in again when the master switch is in the middle position. This prevents a motor under load being cut out owing to a voltage failure and being automatically started again when voltage comes back. This would create a serious danger for the operators in many plants.

Figs. 20 and 21 show details of the various contactor panels. The main bus-bars and the control bus-bars are lodged in the upper part of these panels built of sectional iron while the resistances are placed behind. The contactors, relays and other apparatus are secured to Ferrettite plates mounted on the sectional-iron frames. These plates are easy to machine and, practically, unbreakable so that they are very suitable for the use to which they are put. The different controls of a motor are mounted in sets on the panel and are thus very easy to supervise. Thus, a number of controls for slip-ring motors for reversing service are seen in Fig. 20. There are always three panels placed alongside one another and each carrying

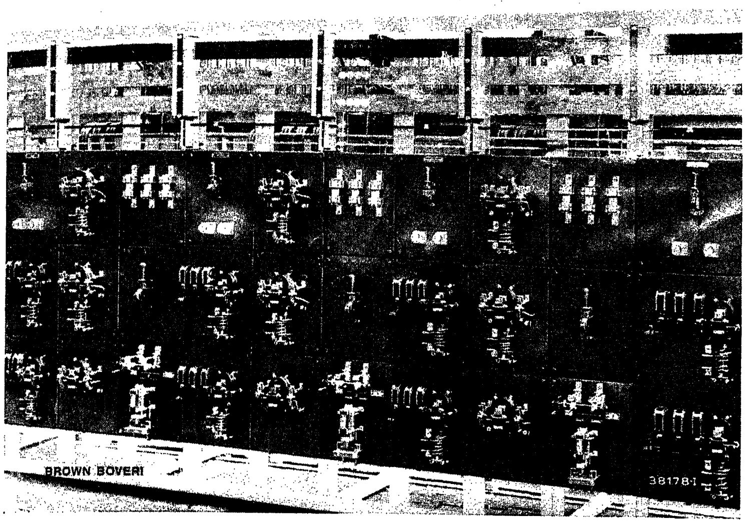

Fig. 20. — Contactor controls for slip-ring motors.

three plates, one above the other; these panels hold on the top, left-hand side the three heavy-duty fuses and just below them the main circuit breaker of the main current. Below it again are placed the thermal overload relay and the low-voltage tripping device. On the right at the top, are seen the lever switch for the controls with its two fuses; below it the two stator contactors for "Forward" and "Reverse" each with an acceleration relay. The third row contains the three rotor contactors, the top two have acceleration relays, as well. Fig. 21 shows the controls for the Demag rollers. The necessary apparatus for one Demag roller set are always one above the other, namely:— the three heavy-duty fuses, the two control fuses, the stator contactors "Forward" and "Reverse" and the contactor to shunt the series resistance. These illustrations show the clear and simple layout of the contactor control.

In the rolling mill itself, the contactor controls along with the control posts belonging thereto are located on two control gangways placed transversally to the rolling mill bay. On these gangways, the contactor panels are separated by chains while being covered in from above. Their exposed position has proved no drawback, up to date. Fig. 22 shows the control gangway behind the two finishing mills with the control post of the 650-mm finishing mill on the right and that of the 450-mm finishing mill, on the left, as well as for the cooling bed belonging thereto.

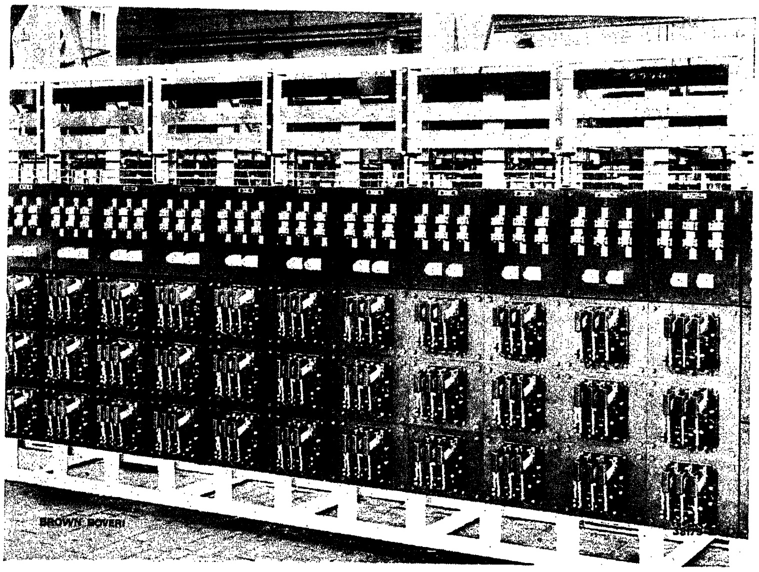

Fig. 21. — Contactor controls for electrically driven rollers.

This plant, equipped for the greater part with Brown Boveri material was put to work, after erection was complete, in the spring of 1934, within the remarkable short time of only a few days. The plant has been running ever since to the entire satisfaction of the owners.

(MS 928) *U. Vetsch. (Mo.)*

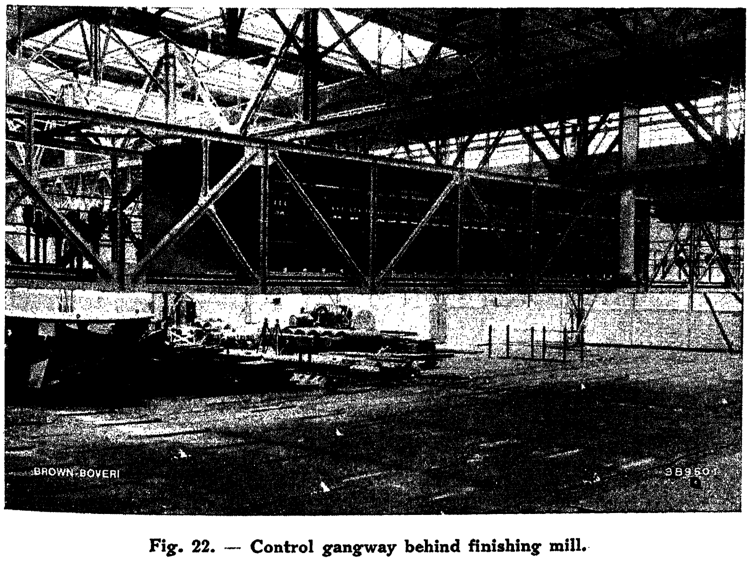

Fig. 22. — Control gangway behind finishing mill.

A STEEL-TANK MUTATOR OF NEW DESIGN, FOR LOW OUTPUTS, COOLED BY ARTIFICIAL AIR DRAUGHT.

Decimal index 621. 314. 652. 2.

IN the course of the last 25 years, the mutator has found a wide field of application as a converter in various branches of D.C. application, such as lighting systems, power distribution, railway networks. The first mutators were made of glass and those of the Cooper-Hewitt type were known as early as the year 1902.

In their first development stage, these mutators were composed of a glass bulb with two or three side arms to take the anodes and having a cathode of mercury at the bottom of the bulb. The finished glass bulbs were exhausted to a high degree, that is to say "formed", after which the connection of the vacuum pump was melted off. It was possible, in this way, to bring the pressure in the bulb down to a very low figure, so that mutators of this type could be operated for several thousand hours without the pressure rising appreciably. The strengths of the rated currents were limited by the reliability of the current bushings and also by the gradual increase of pressure due to the generation of gas inside the bulb. Despite these difficulties, it was found quite practicable to build glass-bulb mutators for rated currents up to 100 A, although the increase in output would appear to be attained at the expense of the length of life of the apparatus. These glass-bulb rectifiers with two or three arms, in the classic Cooper-Hewitt design, are still being built to-day and have proved both reliable and safe in service when used for certain purposes requiring low outputs. For these reasons, they have gained a good name for themselves on the market.

In recent years, considerable progress has been made in glass-bulb rectifier construction, chiefly in the technology of glass making, so that, to-day, glass mutators are being turned out in mass production for outputs up to about 500 A with a guaranteed life of 4—6000 hours. For the outputs involved, six side arms to take the anodes are used, i. e. the same number of anodes as employed in the smaller types of steel-tank mutator.

In the glass-bulb mutators for currents of about 100 to 200 A, the heat due to losses is carried away by natural air draught. In the modern types, for currents of over 200 A, it is necessary to provide a special cooling arrangement with artificial draught. It was, this cooling arrangement which allowed of raising the rated outputs of the different types of glass bulbs, while the shapes of the latter were also modified, so as to attain good cooling conditions.

Owing to the increase in the output of the glass mutators, the danger of back-firing increased, which, in turn, affects the life of the apparatus adversely, so that means had to be sought to reduce back-fires to value which would be, practically, admissible. This has, apparently, been done by changing the shape of the side arms for the anodes which now have a double or treble bend. These changes, however, have increased the voltage drop in the arc, i. e. the losses in the bulb so that, to-day, a voltage drop in the arc amounting to 19 to 22 V has to be reckoned with in a glass bulb which is operated to the maximum of its capacity. At the present development stage, it is perfectly practical to build steel-tank mutators for more advantageous voltage drops in the arc and which are, also, more reliable in service than glass mutators. In order to meet the requirements of practical service, as regards output and voltage, Brown Boveri decided to evolve a new type of small steel-tank mutator, this being a result of numerous enquiries received from clients. The smallest mutator type built up till now had a maximum current rating of 640 A. The new type was designed for a current range of 100 to 400 A; it is adaptable to all voltage ranges met with in industry or traction service; it can also be used in wireless transmitting stations with D. C. voltages up to about 12,000 V.

Brown Boveri were the first firm to take up the manufacture of steel-tank mutators and the development of the latter is due to the pioneering work they accomplished in this field. Further, Brown Boveri played a leading part in the subsequent stage of perfecting the mutator, a process which went on during the last 25 years. The firm is, therefore, very well placed, to-day, to build reliable mutators, for the currents and voltages met with in practice. Further, Brown Boveri were the first firm to develop and introduce the mutator with controlled grids as a practical proposition. It can be said that the Brown Boveri mutator for large output, as an A. C.—D. C. converter has completed a stage of constructive improvement during the last few years. The extensive experience acquired by the firm in the building of mutators was

of great use to them in developing a steel-tank mutator for small outputs which could successfully compete with the glass-bulb mutator, in certain fields. Notwithstanding the experience gained before, it was necessary to study the problem scientifically in order to produce a low-power mutator which would be both simple, reliable and an economical proposition. This study covered both constructive details of the different parts of the mutator and the arrangement of the said parts in the inside of the apparatus. The basic principle adhered to was the attainment of simplicity in design equal to that of the glass mutator; further, the apparatus had to possess indisputable economic advantages. Certain constructive and physical conditions had, thus, to be fulfilled in order to solve the problem. The steel-tank mutator had to be the equal of a glass one, in all points, if it was to be competitive. To begin with, the sealing of the tank and bushings as well as of the accessory apparatus had to be absolutely tight in order to allow of doing away with the supervision of the state of vacuum by means of a vacuum-measuring device, as is done in other mutators. Then, the design had to be such that the cooling system by water, as used in steel-tank mutators of bigger outputs, could be done away with and its place taken by a forced air-draught cooling device. Further the voltage drop in the arc, i. e. the losses in the mutator had to be brought down to a minimum without impairing the safety of the apparatus as regards back-fires. It was not found possible to do away with the vacuum pump set, altogether, but this is an unimportant factor as the pump set only runs for a small fraction of the total operating time. A new high-vacuum pump with artificial air-draught cooling was designed, while the rotary first-stage vacuum pump is of the former standard design. The disadvantages of having to have a vacuum pump set, at all, are far more than compensated for by the unlimited life of the steel-tank mutator; as is known, the expensive glass bulbs of glass mutators must be replaced from time to time. Further, the pump problem is really not of primary importance when the economic advantages to the new mutator of a low voltage drop in the arc, which means low losses, are remembered.

Fig. 1 shows the arrangement of the new mutator set. The set is portable for a voltage range up to 4000 V, it being carried on three swivel rollers; the latter are secured to transversal bars made of oil-impregnated wood, in order to assure proper insulation against earths. When used in wireless transmitting stations, having a voltage range above 4000 V and up to 12,000 V, the set is mounted straight on supporting insulators of a size corresponding to the rated voltage.

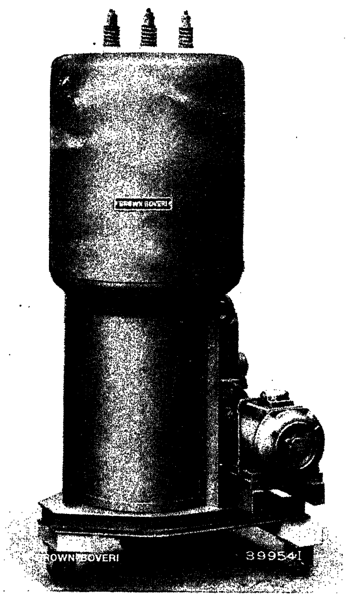

Fig. 1. — Steel-tank mutator for low outputs, with artificial air-draught cooling.

The motor for the propeller-type fan is lodged in the lower frame, which is formed of U-section iron, carrying a sheet-metal shield. The wings of the propeller are overhung on the end of the motor shaft. The said lower frame also carries the high-vacuum pump (Fig. 2). The first-stage pump set is mounted beside the latter, but outside the shield. It rests directly on the lower frame. The mutator itself is supported above the sheet-metal shield. It is, further, surrounded by a light shield which can be easily removed. This latter overlaps the sheet-metal shield of the lower frame and serves to guide the air along the wall of the mutator tank. The design of the whole set is very simple and takes into account the eventual overhaulage or replacement of the auxiliaries.

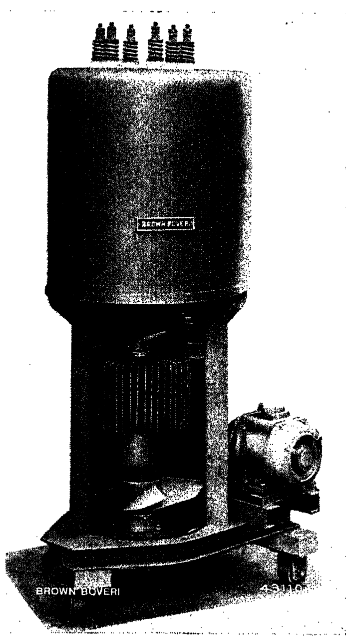

Fig. 2. — Steel-tank mutator for low outputs, with artificial air-draught cooling.
(With the removable sector of the lower shield taken off.)

There is, thus, no water cooling of mutator or high-vacuum pump, this being replaced by forced air draught, produced by a silent propeller-type fan.

The new design differs from the standard Brown Boveri one considerably; it was only definitely decided on after careful tests. The cooling surface of the cylinder is

artificially increased to allow of efficient air cooling. The vacuum cock is lodged under the tank which makes the vacuum pipes short. The ignition gear it also placed below. The mutator has six main anodes and two excitation anodes. The design of the anodes and of the anode sleeves as well as the way in which they are secured are in accordance with the very latest investigations in these fields. The new mutators are equipped with controlled grids if required for special cases, such as voltage regulation on wireless transmission where protection against short circuits is necessary.

The continuous current ratings and the overloads applicable therewith are given in the following table for some standard D. C. voltages.

V	A	kW	Overloads	Transf. second. wind. connected in
250	400	100	50 % for 2 min	Absorption choke connection
600	400	240	100 % for 20 s	
600	300	180	50 % for 2 h	Fork connection
1500	160	240	100 % for 1 min	

The mutator, 12,000 V, for wireless transmitting stations can be loaded with a current of 20 A continually.

The voltage drop in the arc of the mutator is between 17 and 20 V for the loads just given. These are considerably lower values than are attainable with modern glass-bulb mutators of corresponding output. The voltage drop in the arc of the steel-tank mutator with grids is given in Fig. 3, curve 2; it is measured at a temperature of the incoming cooling air of 35° C. The voltage drop, according to curve 2 is measured according to the measuring method introduced by Brown Boveri, with double-phase current transformers (see The Brown Boveri Review, year 1931, page 362) which, practically, gives the losses under ordinary operating conditions. Curve 1 gives the conditions inherent to a glass-bulb mutator. These values are reached by means of the D. C. measurement method in general use, but which give better results than those really attained in operation. A comparison of curves 1 and 2 shows that the steel-tank mutator has a voltage drop in the arc which is about 10 % lower than the one reached with the glass mutator. As is known, there is a relation between the losses or, respectively, the voltage drop in the arc and the pressure inside the tank, the losses rising with the pressure. As the glass rectifiers are maintained in service without vacuum pump set, the pressure in the glass-bulb must rise as time goes on and results in considerable increase in the losses. This does not happen in the new steel-tank mutator, as the pressure in the tank can be brought to the lowest value attainable, at any time, by means of the vacuum-pump set, and it, therefore, works under the best possible conditions as regards efficiency.

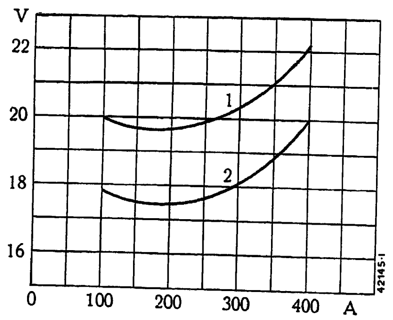

Fig. 3. — Voltage drop in the arc of mutators.
Curve 1.— For glass mutators.
Curve 2.— For steel-tank mutators.

The high vacuum pump underneath the mutator has been specially designed for the new air-draught cooling system. Its internal design corresponds to standard Brown Boveri practice, the interior dimensions, only having been reduced on account of the lower output called for. The external cooling surface of the high-vacuum pump has been increased in order to carry away the condensing heat of the mercury and this has been done by placing a number of cooling ribs on the outside surface of the pump proper. Thorough tests showed that the high-vacuum pump with artificial air cooling has an amply sufficient volumetric output while producing the pressure drop called for. This new pump meets all practical mutator requirements and in rooms at a temperature of 35° C, it is amply sufficient to maintain the low pressure requisite to efficient service.

The first-stage vacuum pump is of the standard Brown Boveri design with automatic closing device, under oil.

All the connecting leads for the starting device of the vacuum pump set and the cooling apparatus are laid, complete, in the frame and are led to a common terminal board. All auxiliary services are insulated from earth and supplied from a special insulating transformer.

No building preparations are necessary in order to erect the mutator set, as all the organs necessary for producing the vacuum and for cooling form a whole with the mutator. Glass mutators for currents of the same strengths are, usually, loaded to their extreme capacity and require complicated inlet and

outlet air ducts for the artificial cooling, which means both building work and considerable space. Usually, the new Brown Boveri mutator is designed for lodging in a cell of the switchboard frame which has to be there, in any case, to take the component parts of the primary and D. C. plant, as well as to take the transformer, which allow of simplifying the laying of the leads.

The design of a mutator plant working alone and delivering about 250 kW is both simple and easy to supervise, as shown in Fig. 4. The frame on the left holds the high-voltage side apparatus, the auxiliary transformer and the starting set. The central frame holds the main transformer while the mutator is lodged in the frame on the right which also carries the D. C. apparatus required. The area taken up amounts to 4·95 m². In cases where the A. C. voltage available on the three-phase side corresponds to the D. C. voltage called for and when, further, the neutral lead on the three-phase system is available, the transformer can be left out and the mutator connected straight to the three-phase system. In a case like this, the area required is only about 2·1 m².

A mutator set of this kind can easily be remote-controlled as for example in railway service, from the nearest station; it can also be made entirely automatic, if desired so as to reduce supervision charges to a minimum.

The preceding paragraphs have been devoted to the description of a new steel-tank mutator for low outputs which can, without a doubt, compete with the glass-bulb mutator, both as regards cost of purchase and of upkeep in service. One of the chief advantages of the glass mutator of not requiring water cooling or any vacuum-measuring gear, is now enjoyed by the new steel-tank mutator, as well. The use of the vacuum-pump set, which has only to run for a small percentage of the time the mutator is in service, can hardly be considered a drawback, and it is one which is more than compensated for by the considerably lower voltage drop in the arc, which means better efficiency and by the elimination of the expensive spare bulbs. The steel-tank mutator has, also, the great advantage of long life, as it has no breakable parts and does not age. Glass bulbs must be changed after a certain service period which has two disadvantages:— firstly, a glass bulb is expensive in itself and, secondly, the ageing of the bulb is marked by a loss of vacuum in its interior so that the voltage drop in the arc, which is not good, even in new bulbs, goes on deteriorating so that the efficiency of the mutator is constantly getting worse. This is such a serious disadvantage, that certain clients have considered it advisable to purchase steel-tank mutators from the first even at a period when they were obliged to put in mutator types of bigger ratings than their requirements called for and when, from the point of view of rating alone, glass-bulb mutator types would have seemed more suitable.

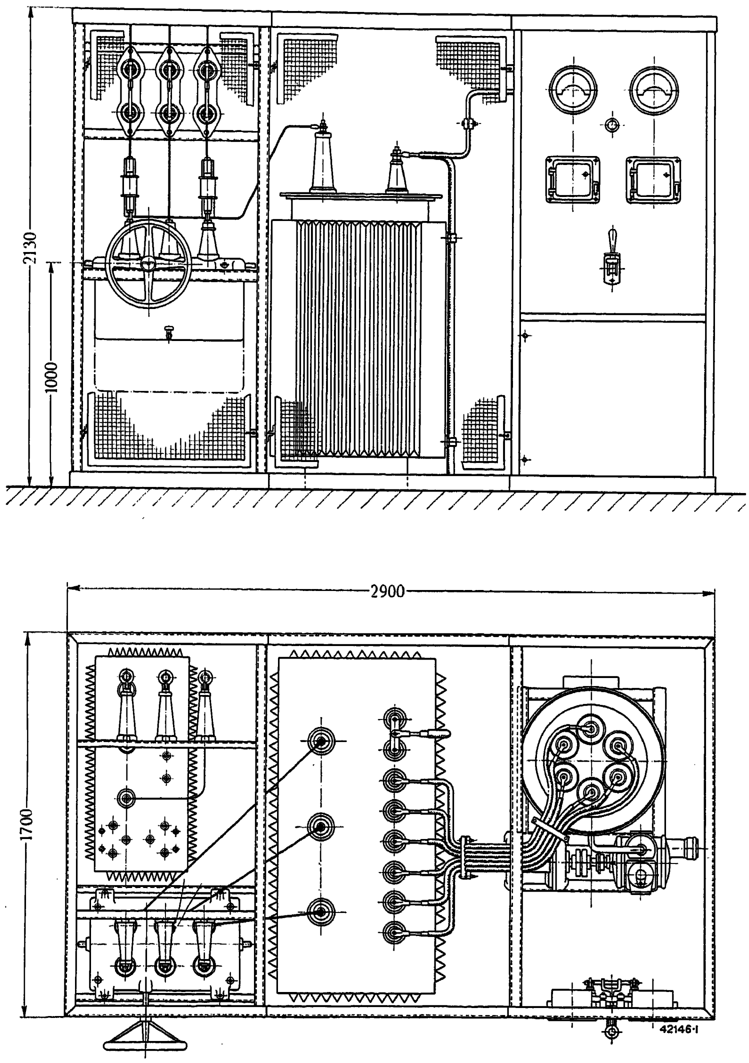

Fig. 4. — Layout of a mutator plant for an output of about 250 kW.

(MS 968) *C. Brynhildsen. (Mo.)*

NOTES.

Motors which can be dismantled for difficult conditions of transport.

Decimal index 621. 313. 333. 0043.

It frequently happens that machinery having to be delivered to far-distant countries, having neither roads nor railways, must be specially designed so as to allow of dismantling them into a large number of parts, for mule, camel or aeroplane transport. An interesting case of this kind occurred recently, where, however, the difficulties of transport

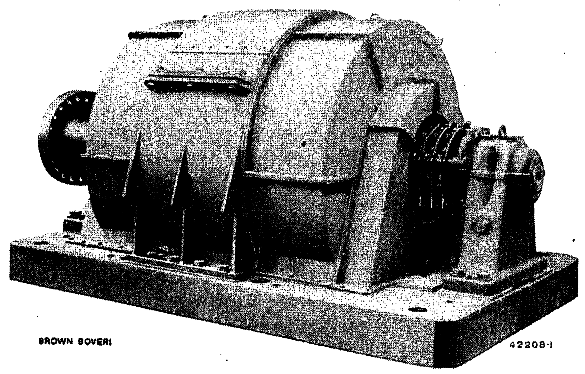

Fig. 1. — Induction motor 1100 kW, 1000 r. p. m. with stator which can be dismantled so as to form three parts.

were not due to lack of roads or railway lines. This was the case of the installation of two induction motors of 1100 kW at 1000 r. p. m. in a mine, their duty being to drive drainage pumps; each motor weighed 8500 kg. Now, the mine shaft had such a small section that the floor area of the cage did not exceed 1·30 m length and 0·98 m width. Under these conditions, standard motor design was out of the question. Brown Boveri, who got the order for these units, built them to a special design which allowed of a division, in axial sense, of the stator into three parts, so that each third part of a stator could go, vertically, into the mine cage. The bedplate was also divided into two parts. These motors have ducts for forced ventilation, the hot air being discharged to outer atmosphere, directly, through ventilating ducts.

(MS 973) *M. Rosset. (Mo.)*

Sectional drive of a cellulose dewatering machine.

Decimal index 621. 34 : 676. 1.

It often occurs that the productive capacity of industrial machines, built up of different sections, can be increased by separating certain of the said sections from the existing common drive and equipping them with their own driving motors. An original single-motor transmission drive is, thus, transformed, at relatively low cost, into a sectional one, which is better suited to the operating conditions of the machine. Thus, for example, the manufacturing speed of paper and cardboard-making machines can be increased by the installation of additional drives which relieve the existing one of part of its duty; the relative speed of the said sectional drives, as regards the main drive, being maintained constant by means of electric draw regulators. It, also, often happens that the drive of certain parts of a machine makes such severe demands on the driving organs that they cannot be met by a transmission drive. In such cases, the machine sections in question are equipped with individual drives, the good regulating qualities of which meet the most stringent driving requirements while they can easily be lodged in the small area available for them, thanks to compact design. Thus, as is summarily explained in the following paragraphs, the single-motor transmission drive of a cellulose dewatering machine in the cellulose works of Attisholz A.-G. (Switzerland) was transformed to sectional drive by putting in several additional drives.

The machine in question, which serves to dewater and to dry cellulose, corresponds to a paper-making machine of medium size in design and method of operation. According to the destination of the product manufactured — home or foreign market — the cellulose manufactured to the so-called sulphite process is either only dewatered and wound up, damp, into rolls or else it is dried, as well. The dry cellulose band about three metres wide, coming from the dry part of the machine, passes, first, through the longitudinal cutter, where it is cut into strips which are then rolled up separately on the reeling apparatus or else cut into sheets by the transverse cutter. The working speed of the machine varies between 18 and 45 m/min according to the strength of the cellulose produced.

Originally, the whole dewatering machine was driven by a single D. C. field-regulated motor of 48 kW through a cumbrous transmission gear. The disadvantages of the mechanical power transmission and power regulating organs used, such as belt drives over step pulleys and conical pulleys, slip couplings, etc., were especially noticeable in the machine sections for cutting and rolling up the cellulose strip and led to the adoption of separate drives for the longitudinal cutter, for the two drums of the reeling apparatus and for the transverse cutter, as well as for the draw roller placed before the transverse cutter (Fig. 1).

The additional drives provided are composed of D. C. motors of 1·5 up to 3 kW max. output, having built, on reduction gears, supplied from a common dynamo with variable voltage. This dynamo is excited at constant voltage from an external source and is driven by belt from the main transmission shaft, of the original drive, so that its voltage and, therewith, the speed of the motors dependent on it adjust themselves nearly proportionately to the speed of the main transmission shaft at each working speed. Small deviations are of no importance as the motors are heavily compounded, the result being that their speeds adjust themselves automatically to the momentary speed of the cellulose strip without subjecting the latter to inadmissible draw strains. All the motors are equipped with regulating starters, contactors, ammeters and Stotz cut-outs and can be started and stopped individually from the operating side of the dewatering machine. The motors of the transverse cutter and reeler are regulated by shunt variation as well as by variation of the armature voltage. In the case of the transverse cutter, this additional regulation allows of a fine setting of the size of the sheet cut and

this over a wide range; while in the case of the reeler the speed of both motors is gradually regulated down by an automatic regulator on each motor, as the diameter of the roll grows, this with constant current consumption, that is to say under an approximately constant draw tension exercised on

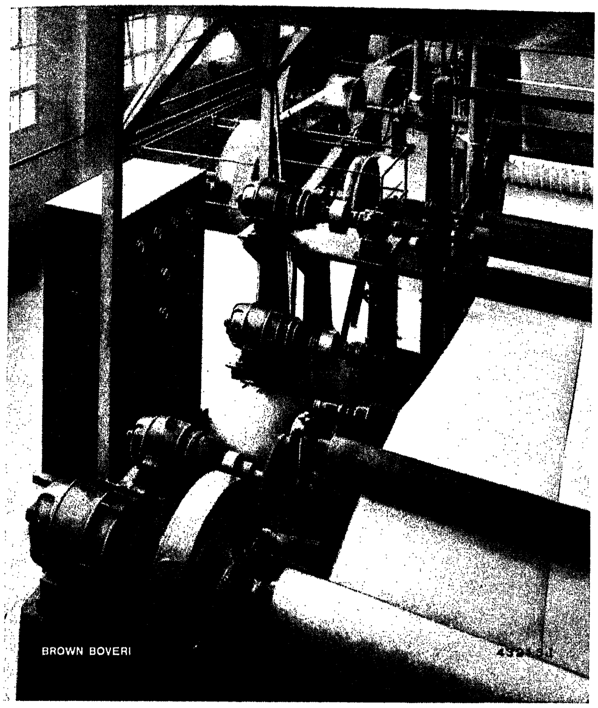

Fig. 1. — Sectional drive of a cellulose dewatering machine.

the cellulose strip being wound up (electro-winder). The wide range of regulation of the driving motors is one of the main advantages of sectional drive as compared to former single-motor drive with which, for example, the size of the sheet cut could only be set very roughly and after loss of time, due to having to change the reduction ratio of a step-pulley belt drive, while the speed of the reeler drums had to be adjusted by hand by constant readjustment of the slip couplings to meet the ever-increasing diameter of the roll.

As is proved by service results, the advantages expected from the transformation of the drive have been entirely attained. Apart from the elimination of a big portion of the transmission gear which increased the safety of operation and gave better access to the various sections of the machine, the client appreciates especially that more uniform and harder rolls of cellulose can now be produced, this with less waste and with less attention from the operators.

(MS 977) *E. Baertschi. (Mo.)*

Extinction coil for the 40-kV system of the Société Générale de Force et Lumière, Grenoble (France).

Decimal index 621.316.935.

AN extinction coil was delivered and put to work successfully by Brown Boveri in the summer 1935 to compensate the system of the Société Générale de Force et Lumière in Grenoble. This coil, placed in the Givors substation, is designed for the following conditions:—

One-hour rating	2510 kVA,
Phase voltage	23 kV,
Frequency	50 cycles,
Maximum current . . .	109 A with tappings for 99, 88, 79, 69, and 54 A.

By means of a tap changer it can be changed over, when dead, to the different current values given above. The tap changer can be operated from the floor of the substation, and is provided with a position-indicating device.

This coil allows of compensating the earth current of the 40-kV system in question, the extent of which is shown in Fig. 1. The transmission lines of the said system are partly single and partly double and, in certain sections, up to 18 lines are carried on the same tower, there being line sections at other voltages carried in parallel.

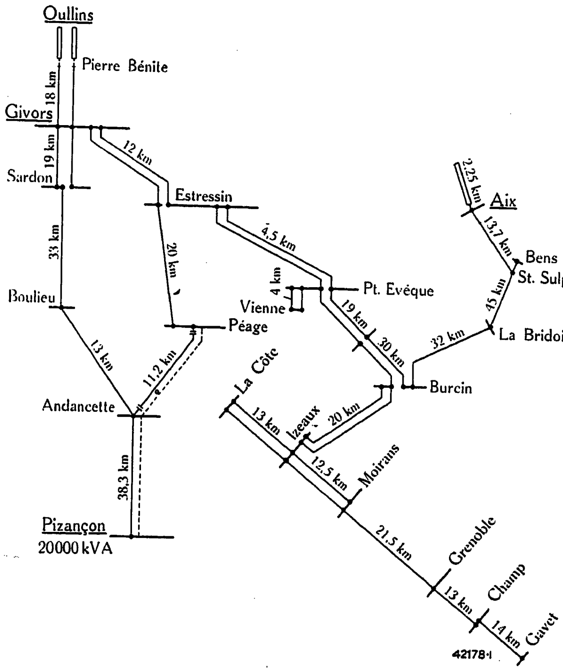

Fig. 1. — General layout of the 40-kV system of the Société Générale de Force et Lumière, Grenoble.

—— Overhead transmission lines in existence.
------ Overhead transmission lines contemplated.
==== Cables.

Now, on this system, the individual phases are either not interposed or insufficiently so, so that the partial capacities of the three phases to earth vary considerably from each other. The result thereof is a considerably big asymmetry voltage which has been determined as being about 4 % for the whole uncompensated system. This voltage, which arises between the neutral point of the system and earth is increased by the connecting up of the extinction coil and it attains its peak value when resonance is reached; it drops rapidly as dissonance increases. When complete compensation is attained this voltage was determined as being 13 kV and at 20 % dissonance it is reduced to only about 4 kV. An asymmetry voltage of the latter magnitude can be tolerated without hesitation, as only the

voltages of the individual phases with reference to earth are asymmetrical, while the composed (line) voltages remain mutually unchanged. The coil put in allows of positive tuning to approximately 20 %, even when the whole network is connected up. With 20 % dissonance tuning the extinction effectiveness of the coil is still very good, as was shown by numerous tests. In service the resonance point and the dissonance tuning can easily be determined by measuring the voltage across the coil. The curve reproduced in Fig. 2 was recorded on the full system length.

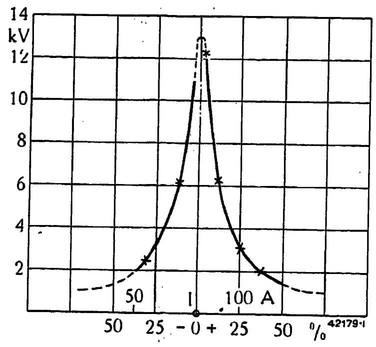

Fig. 2. - Asymmetry of neutral point in kV under ordinary service conditions at different degrees of dissonance tuning of the extinction coil.

I. Point of resonance.

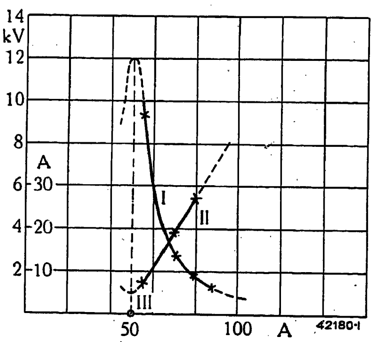

Fig. 3. — Asymmetry of neutral point at reduced length of system and earth current at different degrees of dissonance tuning of the extinguishing coil.

I. Asymmetry voltage, in kV.
II. Residual current which flows over the earth-fault point.
III. Point of resonance.

During the acceptance tests of the coil different extinction tests were carried out. First the point of resonance for the conditions on the system was ascertained (Fig. 3). Curve I of Fig. 3 allows of determining that the resonance current is about 50 A and the peak asymmetry voltage about 12 kV. The second curve II represents the current flowing over the earth fault point measured in the phase having the most disadvantageous value. The measurement reveals that the earth current, which would amount to about 50 A in the uncompensated system (about + 20 % superimposed currents due to higher harmonics) would be reduced to 7·8 A when operating with the 54-A tapping. The higher harmonic currents are included here. Earthings produced by means of a copper wire of 0·05 mm diameter were immediately extinguished on tappings 54 and 69. The arc lasted such a short time that the indicating instruments inserted hardly moved, this although the 69-A tap corresponds to a dissonance tuning of about + 40 %.

Apart from the extinction coil, the plant is equipped with earthing relays for selective tripping of the defective line sections when the earthing is a persistant one. The relays act on the watt component of the earth current which is increased by 20 A by the momentary insertion of an ohmic neutral-point resistance. In order not to endanger the extinguishing of the arc, the resistance is inserted with a time lag of about five seconds; it is left under voltage for about 10 seconds, a sufficient span of time to assure the acting of the earthing relay. After this time has expired the resistance is cut out automatically. In order that different control tests may be carried out, when necessary, the ohmic resistance is dimensioned to allow of its being left in circuit for 2 × 20 seconds. As it is only inserted five seconds after the earth fault appears, the cutting out of passing earthings is prevented these being extinguished by the coil.

(MS 978) *H. Fehlmann. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009. 2): 621. 313. 333. 1.

IN the saw mill belonging to Messrs. Stoffel & Zon in Deventer (Holland) there is a Brown Boveri three-phase motor, Type 8/6, 15 kW, 200 V, 46 cycles, 920 r. p. m., of the slip-ring type, which has been running since the year 1896. This motor drives a planer, and it has been in daily operation with overloads lasting for hours, ever since it was put in. In earlier years these overloads went up to 50 % of the rated output of the motor this without there having been any breakdown over the 40-years span, or

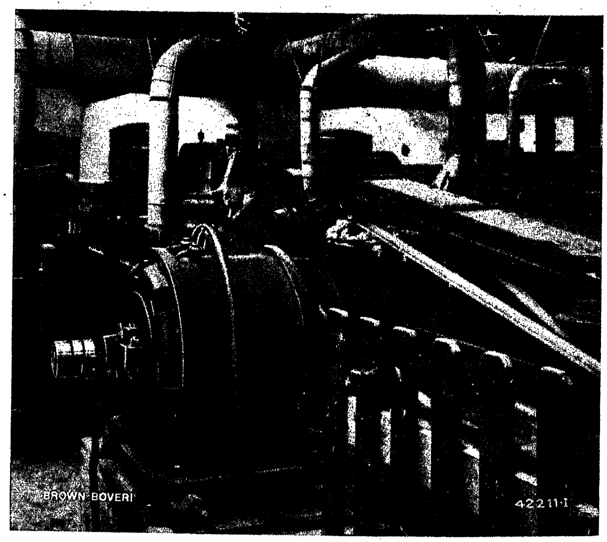

Fig. 1. — Stoffel & Zon, Deventer (Holland), saw-mill. Three-phase motor 15 kW at 200 V, 46 cycles, 920 r. p. m., which has been running since the year 1896.

there having been any necessity to make a repair. The shop number of this machine is 1523. The illustration shows this doughty veteran at work.

(MS 940) *Prop.*

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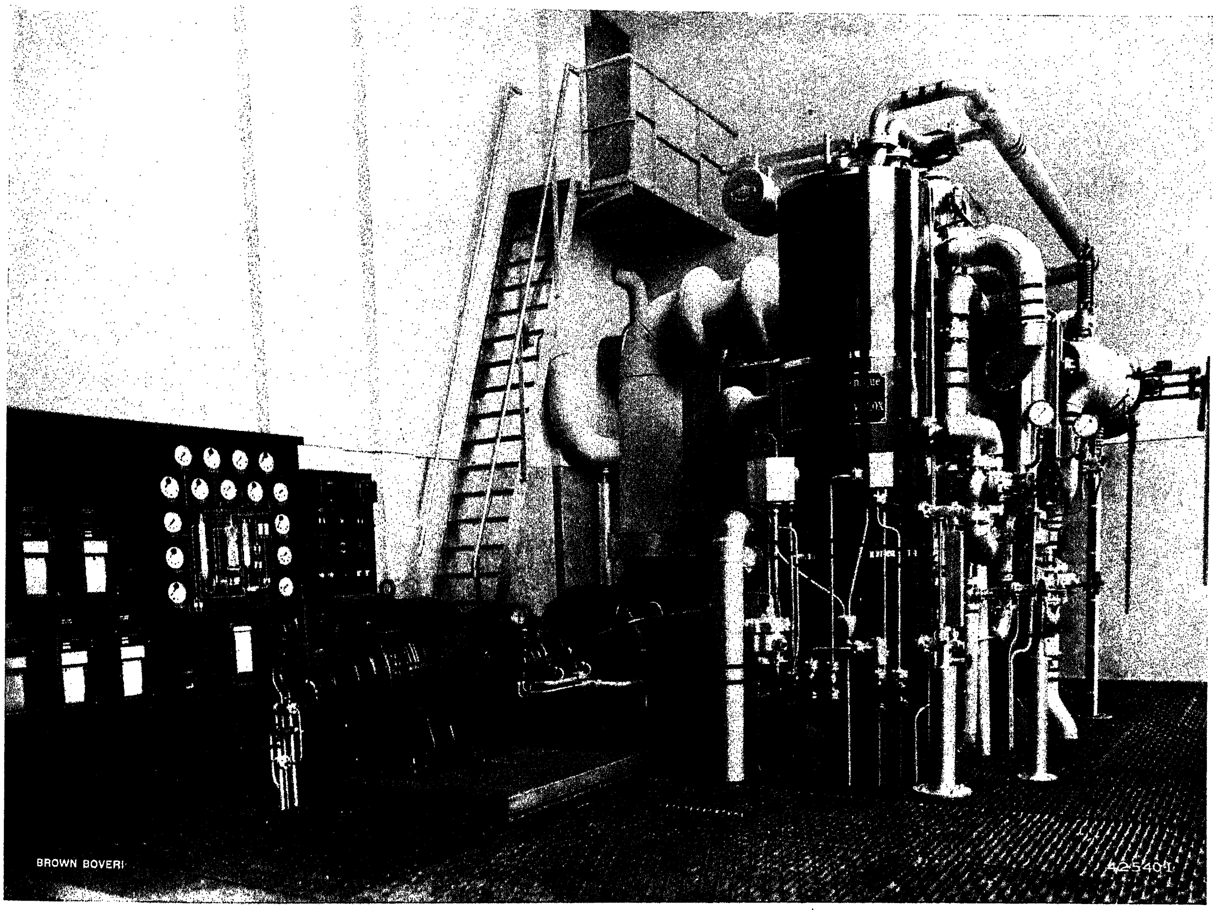

STÉ DES USINES RÉMY, GAILLON, FRANCE.
Velox steam generator, 12 t steam per hour, at 29 kg/cm² and 400° C, fuel-oil firing.

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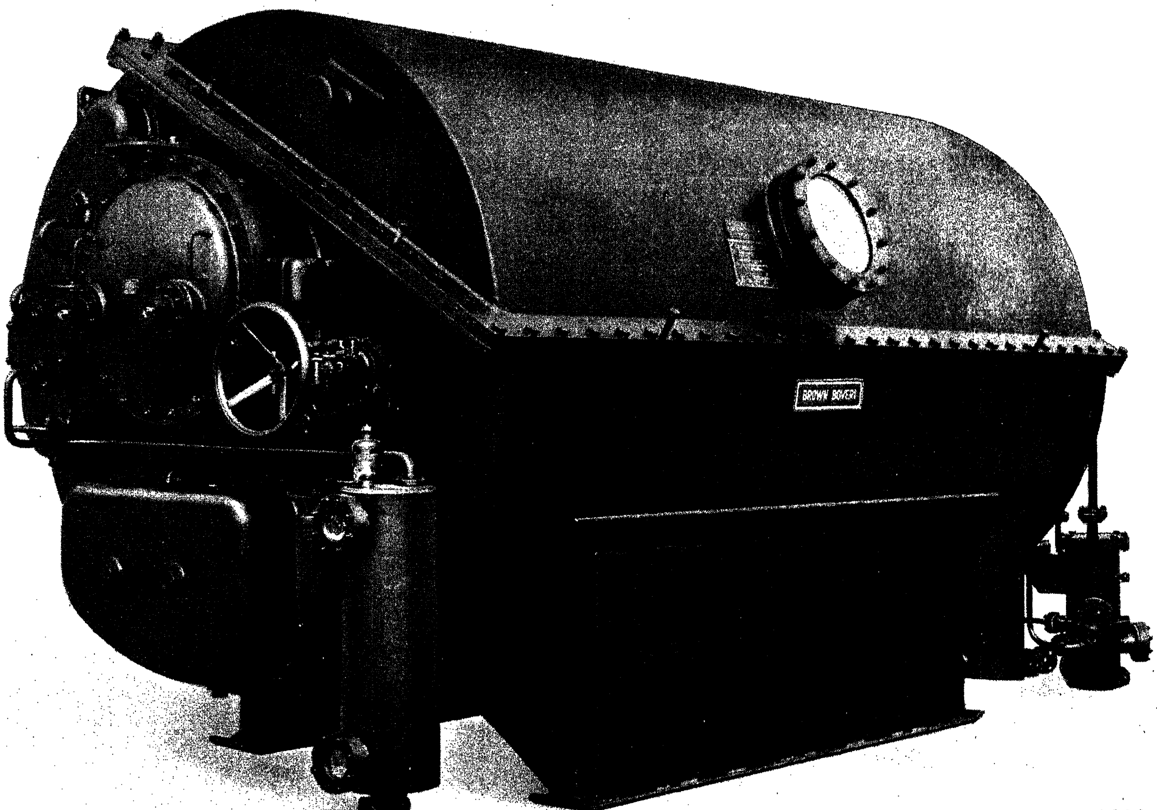

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THE BROWN BOVERI REVIEW
THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)
VOL. XXIII JUNE, 1936 No. 6

THE PART PLAYED BY BROWN BOVERI IN THE DEVELOPMENT OF STEAM POWER STATIONS IN BELGIUM.

Decimal index 621. 311. 22 (493).

BELGIUM has always been one of the most important export countries for industrial products, owing to its mineral wealth and favoured position, as regards international traffic lines.

Apart from the efforts devoted to the development of the key industries of the country—coal mining, metal working, glass, textiles and chemical manufacturing—much energy and thought were given to the development of electric-power production and distribution, this because the cost of the kWh is a factor of importance in the first costs of industrial products. The economic generation and distribution of electric power were recognized as being a factor in the lowering of the cost of the said industrial products and, thus, of giving Belgium a competitive position on the international market for exported goods.

After the end of the great war, however, the primary task to be taken in hand was the rebuilding of wrecked plants, in the shortest time possible, and the enlargement of existing ones in accordance with the needs of the moment. Some attempts were made, it is true, to improve the economic conditions under which existing stations worked, but these were sporadic efforts, for the greater part, and exercised no wide influence.

It remained to the "Commission des Grands Travaux", set up by the Belgian Government, in the year 1927, to define the lines of development to be followed in order to improve power producing and distributing conditions in the whole country.[1]

The chief features of the policy recommended were:— constant logical collaboration in all productive methods; the building of big power stations in accordance with the power absorption capacity of the country and the state of obsolescence of existing power plants, in regions where coal is produced and in regions where much water is available, this in order to bring down the cost of power generation; construction of overhead distribution networks; utilization of surplus power by the parallel operation of all electrical power stations.

[1] Commission des Grands Travaux, Report dated 17. 6. 1927.

A period of constructional activity then set in, encouraged by the favourable industrial situation and by considerable financial support provided by the chief electrical and holding companies and by industry, in general. New power stations were erected, such as that of Schelle, Moll, etc. while old ones were overhauled and enlarged, such as Langerbrugge, Schaerbeek, Bressoux, Antoing, Ville-sur-Haine, etc.

In order to fulfil the programme, namely to build big power stations and distribution plants, on a sound economic basis, it was necessary to have available technical facilities, far in advance of those of former years. The engineering industry was, however, well equipped at the time the programme was taken in hand, to fulfil all the new requirements. Among the features which characterize the plants which belong to the new programme of development, the following may be mentioned:—

Application of recently acquired knowledge on the properties of steam, such as its behaviour under high pressures and high superheat temperatures, the advantages of intermediate superheating, of preheating feed water by steam bled from the turbine or by exhaust steam from steam-driven auxiliaries, the preheating of combustion air, which all go to improve the thermal efficiency of the steam-turbine cycle; improvements in the science of testing materials.

Utilization of bigger steam turbine and boiler units, giving the highest thermo-dynamic efficiencies possible while utilizing material to the most economical extent and, at the same time, providing every safeguard as regards service reliability.

The use of pulverized fuel and the improvements in methods of combustion.

Evaporation of make-up water by steam bled from the turbine. Deaerating condensate.

Advantageous power-house layout with better design and arrangement of auxiliaries.

Construction of high-voltage lines and installation of circuit breakers of high rupturing capacity, etc.

The Brown Boveri two and three-cylinder steam turbine was a machine well suited to the requirements

of big generating stations, as it met, successfully, all the needs of the said plants, thanks to the thorough development of every individual detail. We would only mention, here, the most striking characteristics of this type of machine, namely:— the subdivision of the heat drop into numerous stages, the effective distribution between different cylinders which form the high-pressure, medium-pressure and low-pressure parts of the machine; the elimination of a balancing piston by making the axial thrust of the high and medium cylinders compensate each other and by dividing the low-pressure cylinder into two symmetrical parts, which increases the exhaust section and, thus, decreases the losses in the exhaust branches; special measures taken to allow of expansion due to temperature rise; the glands, bearings and high-pressure valves all of special and proved designs; governing without rods and entirely by oil under pressure; special devices introduced to drain water from the low-pressure sections, these being in the form of ring channels and feed-water preheating by bleeding in the lower stages, in order to reduce the braking effect of water; specially hardened blade edges in the last blade rows, to diminish erosion.

The basic principal advocated by Brown Boveri of having several cylinders—notably the three-cylinder type of turbine—which was so much opposed, at one time, is admitted generally to-day, and has found many imitators.

It is, therefore, not to be wondered at that, when the Belgian rationalisation programme was being considered, Brown Boveri were given the major part of the turbine orders. Between 1903 and 1923 about 120 Brown Boveri turbines were delivered to Belgium, producing a total of about 234,000 kW, while, up till to-day, the number has increased to 260 units producing a total of about 963,000 kW.

Before enumerating the most important plants equipped by Brown Boveri, mention should be made

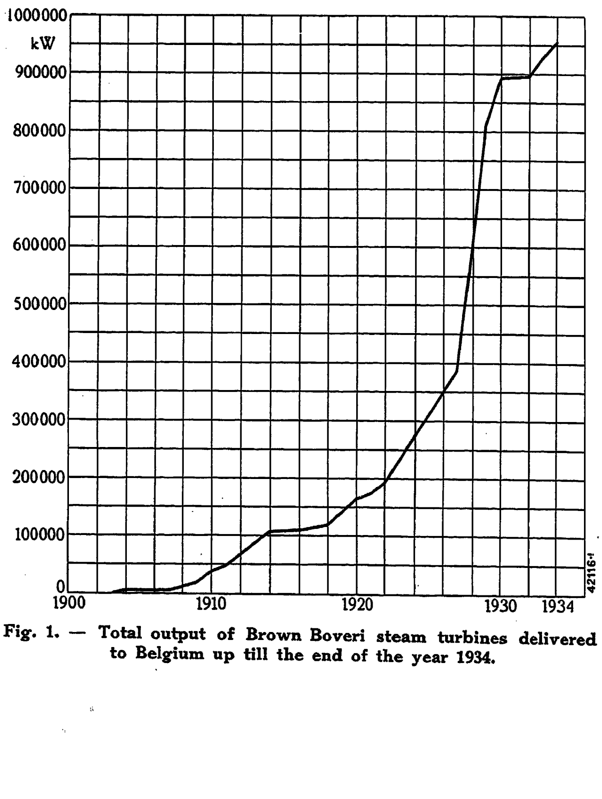


Fig. 1. — Total output of Brown Boveri steam turbines delivered to Belgium up till the end of the year 1934.

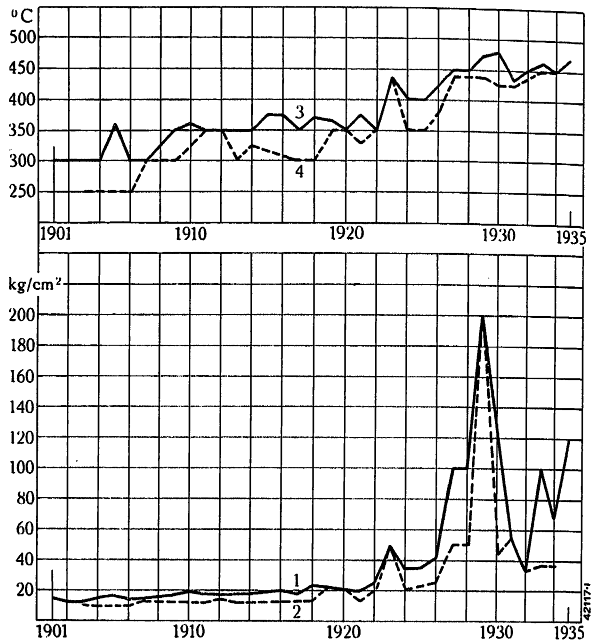


Fig. 2. — Evolution in high pressures and high temperatures used in Brown Boveri turbines from 1901 to 1935.

1, 3. In the whole world. 2, 4. In Belgium.

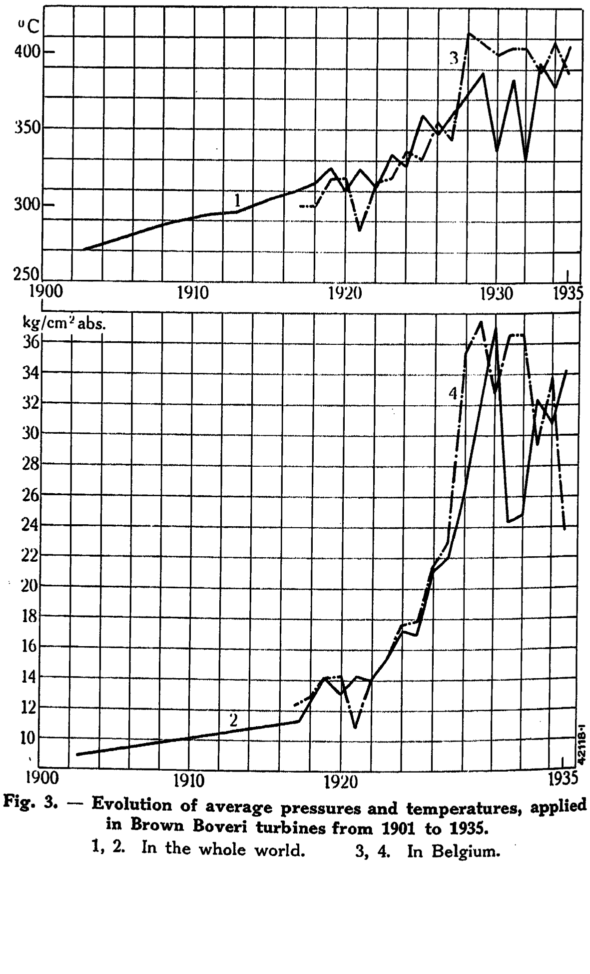


Fig. 3. — Evolution of average pressures and temperatures, applied in Brown Boveri turbines from 1901 to 1935.

1, 2. In the whole world. 3, 4. In Belgium.

of the main causes which were in favour of the introduction of high steam pressures and high superheated temperatures into Belgian thermal plants.

In earlier days, Perkins, Serpollet, Schmidt, De Laval and others demonstrated, theoretically, the directives to follow in order to attain better utilisation of the steam and experimental boilers were built for high pressure and temperatures. These investigations remained, however, in the experimental stage, because, at that time, the manufacturers could not turn out industrial plants for producing power or heat on a large scale under these new conditions, i. e. suitable steam turbines and boilers. Thus, in the year 1920, in Langerbrugge, it was found impossible to put in a boiler producing a pressure of 25 kg/cm^2, within the time which was required, because 20 kg/cm^2 gauge was the highest pressure considered attainable.

Progress in the manufacture of building materials tenacious work in the field of development as regards boilers and steam turbines, the irresistable urge towards greater achievements animating the manufacturing firms in general and, it may be truthfully said, Brown Boveri in particular, finally made available to the power station engineer the possibilities for expansion along the new lines.

While other countries were marking time in discussing the real utility and economy of applying high pressure and using highly superheated steam, Belgium did not hesitate to put these new principles into practice. As early as the year 1919, Monsieur L. Herry, Director of the *S. A. des Centrales Electriques des Flandres, Langerbrugge,* the pioneer, to whom all credit is due for the introduction of high steam pressures into industrial plants, had under consideration a project laid before him by Brown Boveri for a steam turbine operating at 84 kg/cm^2 abs, 390° C at 18 kg/cm^2 gauge back pressure.

In order to eliminate intermediate superheating of the steam and also to allow of connecting up to the existing steam system, at 20 kg/cm^2 gauge, the high-pressure steam turbine was finally built for live steam at 51 kg/cm^2 abs, 442° C and 21 kg/cm^2 abs back-pressure[1]. This turbo set, of 1625 kW terminal output, erected in 1923, was the first high-pressure plant in Europe for power generation[2].

This turbine works as a first-stage unit along with one of the existing 6600-kW steam turbines.

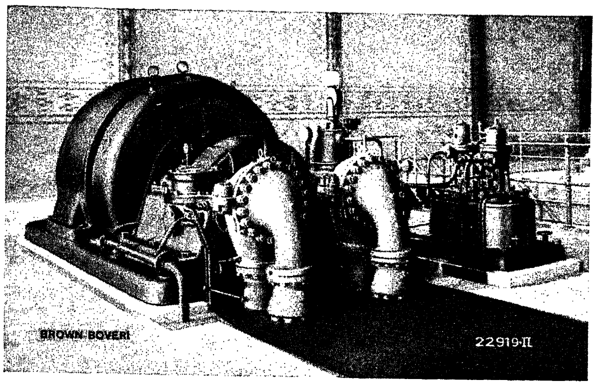


Fig. 4. — S. A. des Centrales Electriques des Flandres, Langerbrugge (Belgium).
High-pressure, first-stage turbine. Steam pressure, 51 kg/cm^2 abs, temperature 442° C, with reduction gear to drive a three-phase generator 2500 kVA, 12,000 V, 50 cycles, p. f. = 0·8, turbine running at 8000 r. p. m., generator at 1500 r. p. m.

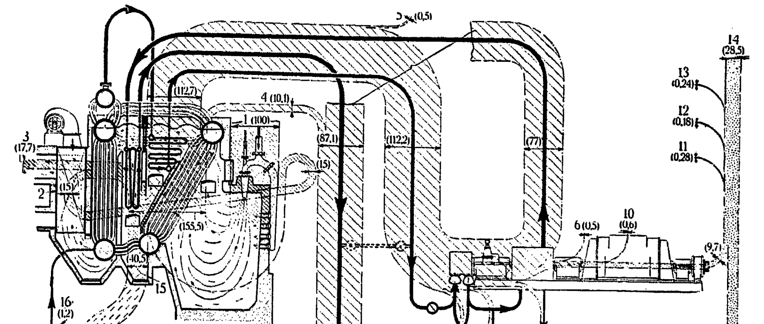


Fig. 5. — Diagrammatic layout of a high-pressure 30,000-kW plant, with a 20,000-kW main turbo-set and a 10,000-kW high-pressure, first-stage turbine. Heat distribution according to the Sankey diagram. Efficiency of fuel 28·5% (see also foot-note 2).

[1] W. G. Noack, V.D.I. 1926, page 711 "Dampfturbinen für hohen Druck".

[2] W. G. Noack, V. D. I. 1923, page 1153 "Hochdruck und Hochüberhitzung" and, also, "Langerbrugge Power Station", Engineer 1926, p. 571.

The high and low pressure turbo set thus formed delivered a terminal output of 8225 kW, the thermal efficiency attained by the combined plant being 28 %.

As far as is known, large-scale preheating of feed water was also applied in this plant for the first time, in Belgium. This is carried out in three stages through the exhaust steam from the sealing gland of the high-pressure turbine and by exhaust steam from the turbo feed pump, by a tapping on the low-pressure blading of the existing steam turbine, and, finally, by tapping the steam collector pipe at 20 kg/cm². The feed water temperature thus attained is 196° C.

With the steam characteristics chosen, as well as with the introduction of preheating of feed water and the other improvements mentioned above, it was found feasible to bring the thermal efficiency of thermal plants considerably closer to the thermal efficiency of Diesel generating stations (Fig. 5).

On account of the most encouraging results attained with the first high-pressure turbine built, it was decided, in 1927, to develop the whole steam system for a pressure of 50 kg/cm² gauge, this by putting in a further first-stage turbo-set of 6600-kW which could supply the existing three 6600 kW low-pressure turbo-sets. This turbine was also designed for 51 kg/cm² abs, 442° C and a back-pressure of 21·5 kg/cm² abs.

The rapid expansion of the power demands made on the Langerbrugge Power Station, however, called for a quicker expansion of the power generating capacity than had been reckoned with. Thus, in the years 1928 and 1929, three three-cylinder turbo sets, each of 25,000 kW, 51 kg/cm² abs, 442° C were erected. These turbines are also designed for feed water preheating up to 175° C, through four bleeding stages on the turbine, the lowest of which is in the low-pressure part both for preheating and water draining. These were the first big steam turbines which utilized the whole heat drop from 51 kg/cm² abs down to vacuum, in one single set.

In the year 1929, a further stage of development was begun:— the 200 kg/cm²-pressure stage. By making use of a Benson boiler, in which vaporisation should take place under critical pressure, steam at over 200 kg/cm² gauge was generated and utilized in a high-pressure first-stage turbine inserted between the high-pressure side and the 50 kg/cm² system. This turbine is used to drive the boiler feed pump and an induction generator as well, which can run as a motor, if so required. The terminal output is 4000 kW, 200 kg/cm² gauge, the temperature worked to is 430° C, the back pressure 60 kg/cm² abs and the steam consumption 112 t/h[1].

Thus, the Langerbrugge power station gives an impressive picture of the remarkable evolution in power-station design during the last decade, which applies to other countries as well as to Belgium. The choice of a pressure of 200 kg/cm² was determined by the particular design and method of operation of the Benson boiler. It can be proved by calculation that, from a thermal point of view, a pressure much exceeding 100 kg/cm² for outputs of this magnitude is hardly justifiable, to-day. As regards superheating, 500° C should be the upper limit, with regard to preservation of the plant, in the stage of development reached to-day.

The following paragraphs give a summary of some interesting plants.

Société d'Electricité de la Campine, Moll power station.—This station is interesting as being the first big Belgium plant in which multi-cylinder steam turbines were placed, and in which those new principles advocated by Brown Boveri for steam power stations were applied, which were largely used, afterwards, in the other stations mentioned here.

Among these principles, mention can be made of:—

The preheating of the condensate by bleeding the turbine, in several stages, the lowest preheater (at abt. 0·25 to 0·3 kg/cm² abs) being used as a water drainage preheater.

Deaeration of the condensate in the condenser itself or in the preheater while eliminating special deaerators.

[1] See The Brown Boveri Review, January 1930 and 1931.

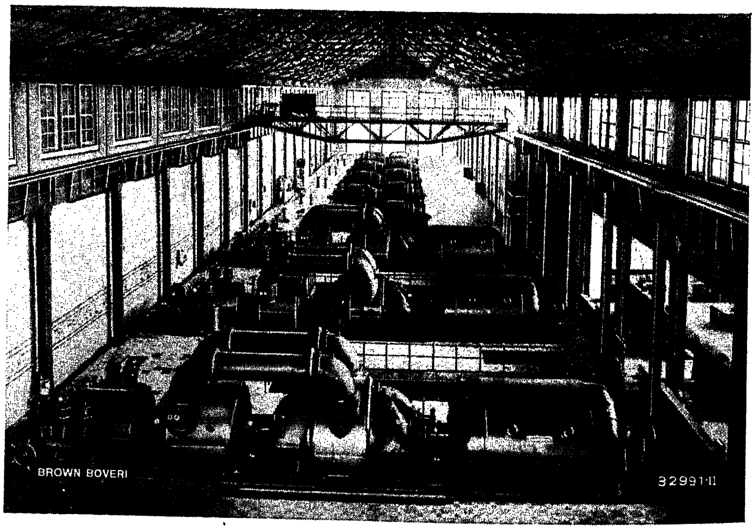


Fig. 6. — S. A. des Centrales Electriques des Flandres, Langenbrugge (Belgium). All the sets were delivered by Brown Boveri. In foreground:— three 25,000-kW high-pressure turbo-sets.

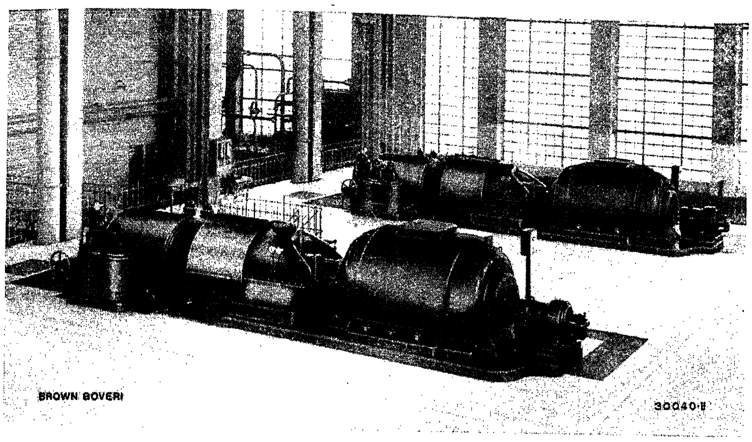


Fig. 7. — Société d'Electricité de la Campine Brussels (Belgium). Moll power station.
Two two-cylinder turbines each of 10,000 kW, 26 kg/cm² abs, 375° C, 3000 r.p.m., coupled with generators by other makers.

A closed feed-water circuit, through using intermediate-pressure storage tanks with a cushion of steam for the preheated feed water, in order to maintain the pressure in the tank and prevent formation of steam in the feed-water pumps; in the latest plants this is connected with the condensers, in order to keep the condensate free of gases.

Evaporation of the make-up water in the evaporators by bled steam and combinations with the preheating plant; lately, this has been arranged between the second and third bleeding point, in two stages in series as a super-pressure evaporator, to maintain sufficient quantity of evaporated water, at partial loads.

Twin condensers for three-cylinder turbines and, lately, one condenser with double steam flow, that is to say one with two exhaust branches, condensers in two parts allowing of cleaning the tubes while maintaining the condenser in service.

Combined pump sets, consisting of cooling-water pump, ejector pump and condensate pump driven normally by motor and having a steam turbine as spare which takes over the load automatically if the electric current supply fails. An auxiliary pump set for a part of the volume of cooling water, driven by motor, which can be stopped when the load is small or the cooling-water temperature is low, in order to economize power used for condensate duty.

The following units were placed in the Moll power station:—

2 two-cylinder condensing turbines each of 8/10,000 kW terminal output.

1 three-cylinder condensing turbine 16/20,000 kW terminal output, 3000 r.p.m., 31 kg/cm² abs, 425° C at inlet valve.

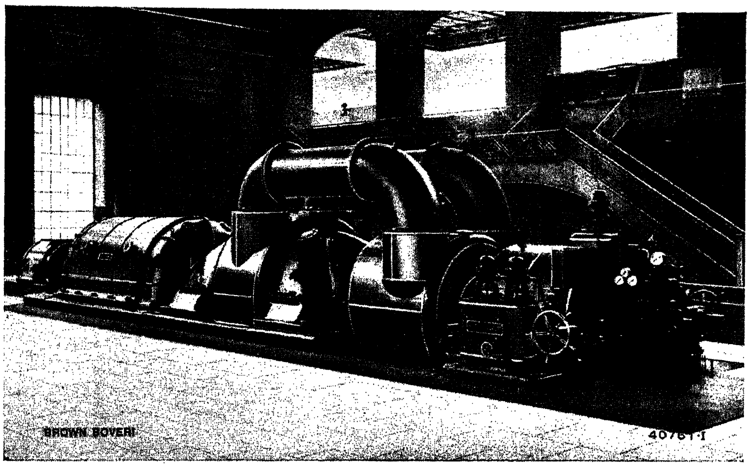


Fig. 8. — Société Interescaut, Schelle power station.
Three-cylinder turbo-set of 31,700 kW, 36 kg/cm² abs, 425° C, 3000 r.p.m., with main generator 40,000 kVA, 10,500 V, and station generator 2125 kVA, 3150 V, 50 cycles.

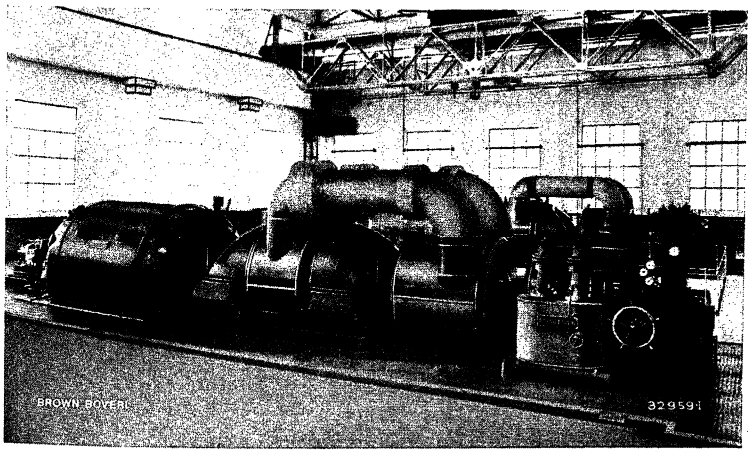


Fig. 9. — S. A. Ammoniaque Synthétique et Dérivés, Brussels, Sluiskil (Holland), two three-cylinder turbo-sets each of 20,000 kW, 36 kg/cm² abs, 425° C, with a three-phase generator 30,300 kVA, 6000/6600 V, 50 cycles, 3000 r.p.m.

Preheating up to 125° C in the two-cylinder turbines by means of two preheaters and by means of three in the case of the three-cylinder turbine, combined with evaporation of make-up water. The latter turbo-set has, further, an air cooler to cool the generator air, in closed circuit with a signalling device when the admissible air or water temperatures are exceeded.

Société Interescaut, Schelle power station. — A turbo set 31,700 kW supplied with steam at 36 kg/cm² abs, 425° C, 3000 r.p.m. was delivered here; it comprises:—

1 three-cylinder steam turbine.

1 main generator 30,000 kW, p. f. = 0·75, i. e. 40,000 kVA, 10,500 V, as well as a station generator, on the same shaft, 1700 kW, 3150 V, for the auxiliary station requirements.

1 twin condenser built for salt water, 7500 m^3/h. Two sets of pumps, each comprising vertical condensing and ejector pumps of which one as spare (cooling water delivered from a central pumping station).

A three-stage preheating plant for 165° C.

A closed circuit air-cooling plant with signalling device, for the generator air, an auxiliary set in the basement composed of a fan to provide air for the generator, a three-phase induction motor as driving motor supplied from the auxiliary system of the station (station generator), a D. C. motor as spare, as well as an exciter and cooling-water pump on the same shaft.

S. A. Interbrabant, Schaerbeek power station, Brussels. — Brown Boveri delivered four three-cylinder condensing turbines to this station, each built for 20,000 kW and supplied with steam at 36 kg/cm^2 abs and 425° C, at the inlet valve, but designed for 44 kg/cm^2 abs and 470° C, built for preheating up to 125° C in three stages and evaporation of 3850 kg/h of make-up water at full load, by means of two evaporators connected in series. Twin condensers for salt water were put in for a total quantity of water of 4500 m^3/h, a combined condensing pump set and an auxiliary pump set, an air cooler for the generator with signal device. Special attention was paid to regain the different drain losses.

Société de Gaz et d'Electricité du Hainaut, Ville-sur-Haine power station. — Two 23,000-kW steam turbines were delivered to this station along with complete condensing plants, preheaters and evaporating plants. With the exception of the condenser, for which a two-part two-exhaust salt-water condenser for 4000 m^3/h with two steam exhaust branches and of the deaeration of the intermediate-pressure tank in the condensers, the layout is exactly similar to that of Schaerbeek. This plant, as well, was designed on the same principles as Schaerbeek by the Soc. Electrorail in Brussels, to which concern the Soc. de Gaz et d'Electricité du Hainaut is attached.

The Schaerbeek and the Ville-sur-Haine power stations are built on modern simple lines. The harmony of the whole design with its four turbo-sets is especially pleasing and difficult to equal.

Société Intercommunale Belge d'Electricité. — Brown Boveri equipped several power stations as well as delivering different smaller turbo sets to this company. Among the big stations:—

Bressoux power station with two three-cylinder condensing turbines each of 30,000 kW at the terminals, 3000 r. p. m., supplied with steam at 36 kg/cm^2, 425° C (peak 470° C) besides a three-phase generator, 30,000 kW p.f.=0·75, 40,000 kVA, 10,500 V, 50 cycles, for the second set; each set has a complete condensing and preheating plant with four preheaters to preheat up to 165° C, composed of a motor-driven condensing pump set and an auxiliary cooling-water pump set, and auxiliary set in the condenser basement with fan, three-phase driving motor, exciter, the air coolers with signal device.

Monceau s/Sambre power station with two complete turbo sets each of 4000 kW with *first stage-turbines* supplied with steam at 50 kg/cm^2 abs, 450° C with exhaust steam led to the low-pressure pipe at 19 kg/cm^2 abs. With the installation of these first-stage turbines, the Soc. Intercommunale Belge became partisans of high-steam pressures. It was possible by putting in the said units to raise the power of the plant by 8000 kW without increasing the cooling water volume.

Soc. Néederlandaise d'Azote, Brussels, Sluiskil power station. — This station on the Ghent-Terneuzen canal (Holland) is equipped with two complete three-cylinder turbo-sets each of 20,000 kW. The turbines are supplied with steam at 36 kg/cm^2 abs, 425° C, maximum temperature 450° C. The exhaust steam is condensed in twin condensers built for salt water, the volume of cooling water handled being 4300 m^3/h. This water is delivered by a combined

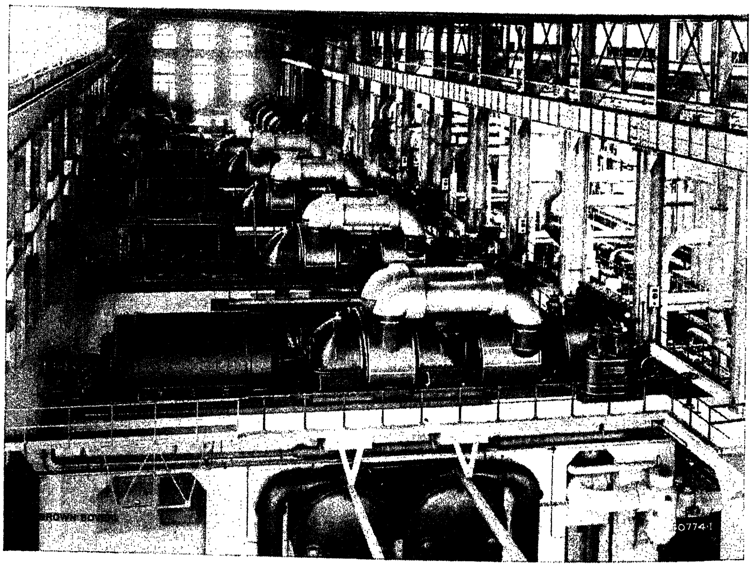


Fig. 10. — Société Interbrabant, Brussels. Schaerbeek power station.
Machine hall containing four turbo-sets each of 20,000 kW, 3000 r.p.m., with three-cylinder turbines, 36 kg/cm^2 abs, 425° C, maximum 44 kg/cm^2 abs, 470° C. Feed-water preheating up to 125° C. On the right:— pump hall with feed pumps, preheaters, evaporators and feed-water tanks.

pump set and an auxiliary pump set. Preheating is carried out in three stages at 125° C and evaporation of 4000 kg/h of make-up water is effected by means of two series-connected evaporators. Each generator develops an output of 30,300 kVA at p. f. = 0·66, voltage 6000/6600 V, frequency 50 cycles. The generators are cooled from an independent source, the fan being lodged in the basement. This allows of circulating the cooling air by a slow-running fan of high efficiency. It is technically remarkable that the motor driving the fan is connected up straight to the generator terminals and not through a starter; it, therefore, runs under generator voltage. Relays are inserted on its leads to protect it against overloading or short circuits. These relays cause the generator excitation to be lowered and the generator to be cut out in cases of trouble.[1]

This solution has the advantage of allowing of dispensing with attendance on the motor, which starts up, automatically, with the generator and remains running as long as the generator.

Cie Auxiliaire d'Electricité, Antoing. — Apart from a 6400-kW low-pressure turbine and a first-stage turbine, 3000 kW 42 kg/cm² abs, 425° C at the inlet valve, 14 kg/cm² abs back pressure, Brown Boveri delivered a 20,000-kW three-cylinder turbine built to the same steam conditions as set out above and for a maximum pressure of 46 kg/cm² abs, 450° C along with the complete condensing and three-stage preheating plant to heat up feed water to 131° C at full load.

The importance of the deliveries made by Brown Boveri for big power electric generation is shown clearly by the following table:

Table of three-cylinder turbines delivered to Belgian firms.

Plant	Number of units	Output per unit at terminals kW	Total in kW	Steam conditions: Pressure kg/cm² abs	Steam conditions: Temperature °C
Antoing . . .	1	20,000	20,000	42	425
Bressoux . .	2	30,000	60,000	36	425
Langerbrugge	3	25,000	75,000	51	442
Moll	1	20,000	20,000	31	425
Schaerbeek .	4	20,000	80,000	36	425
Schelle . . .	1	31,700	31,700	36	425
Sluiskil . . .	2	20,000	40,000	36	425
Ville-sur-Haine	2	23,000	46,000	36	425
	16		372,700		

Apart from a large number of average and small turbo-sets, the enumeration of which would lead too far, there are a few smaller modern power stations which present interesting features:—

[1] The Brown Boveri Review, January 1931, page 49.

S. A. des Hauts Fourneaux de Thy-le-Château et Marcinelle à Marcinelle. — This industrial power station is entirely equipped with Brown Boveri sets. Since the year 1906 up till the last enlargement, Brown Boveri has delivered a total of six turbines for an approximate total output of 10,000 kW, to drive generators and blowers. The new set of 10,000 kW terminal voltage delivered is composed of:—

1 two-cylinder turbine with two-stage preheating to 125° C at full load and evaporating plant for 2100 kg/h of make-up water, for steam at a pressure of 32 kg/cm² abs, max. 38 kg/cm² abs, 425° C at the inlet valve.
1 turbo-generator 12,500 kVA, p. f. = 0·8, 3000 V, 50 cycles.
1 complete condensing plant for fresh water, 2500 m³/h and a motor-driven pump set.

S. A. des Charbonnages de Wérister, Beyne-Heusay. — This plant is remarkable from the fact that the power station is over the pit and that the boilers are fired with low-grade very cheap coal. The turbo-set delivers current to the system and also its excess power to the same. The characteristics of this plant are:—

1 turbo set 10,000 kW terminal output with two-cylinder turbine three-stage preheating to 155° C and evaporating plant for 2500 kg/h make-up water; supplied with steam at 31 kg/cm² abs, 425° C;
1 generator 12,500 kVA, p. f. = 0·8, 6/6600 V, 50 cycles, two-part fresh-water condenser for 2100 m³/h with motor-driven condenser pump set.

Solvay & Co., Brussels. — Brown Boveri has delivered a big number of steam turbines, since the year 1926, to this important concern. These units were for Belgium, but also for various foreign plants. In all 27 sets were delivered with a total terminal output of about 38,700 kW. These turbines work as condensing-extraction-back-pressure units. Mention must also be made of a Velox steam generator for gas firing delivered for a foreign plant of this concern and built for 18 t/h, 36 kg/cm² abs, 400° C.

S. A. des Mines et Fonderies de Zinc de la Vieille Montagne, Baelen power station. — Two turbo sets were delivered here, each of 7200 kW, each composed of a two-cylinder turbine with two-stage preheating at 125° C with evaporation of make-up water, live-steam pressure 36 kg/cm² at 425° C, a complete condensing plant with combined pump set. *This is one of the most modern plants for this range of output.*

The uniformity of temperature and pressure throughout these stations is a striking feature, showing that, at the time the plants were built, the advantages of high steam pressures were recognized.

The extent of Brown Boveri's participation in the development of Belgian power generating plants will be realized from the number of sets delivered.

(MS 939) *Ad. Baumann. (Mo.)*

SOME NOTES ON THE QUADRATURE REGULATING TRANSFORMER.

Decimal index 621. 314. 214. 0012.

I. OBJECT AND FIELD OF APPLICATION.

THE quadrature regulating transformer, inserted on a closed-ring system, serves to regulate the partition of the load transmitted between the two branches of the ring or to prevent circulating currents being set up. If this transformer is inserted on a simple, open line, it can be used to regulate the voltage as, for example, to re-establish the symmetry of a voltage system.

The quadrature regulating transformer is used in the three following typical cases:—

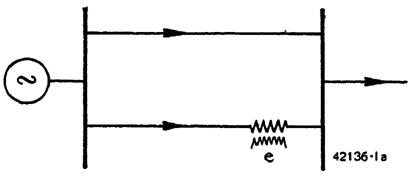


Fig. 1. — Power station supplying two parallel lines.
e. Voltage of quadrature transformer.

(a) *A power station works on two parallel lines* (Fig. 1).— Under usual conditions, the power transmitted is divided between the lines in inverse ratio to the impedance of the latter. If now an auxiliary voltage e is introduced on the loop formed by the two lines, it becomes possible to divide up between the two lines the power transmitted, in the ratio desired, and, thus, to relieve an overloaded line or a transformer inserted on that line, to reduce the losses and heat generated on same etc.; in short, a rational distribution of load becomes feasible.

(b) *Several power stations are connected together on a loop* (Fig. 2).— Station C gets its power from B or from A. Under ordinary conditions, the power delivered by station B, for example, is divided up between the lines n and o-m, as under (a), that is according to the characteristics of the branches of the loop. As compared case (a), the present one offers the possibility of making certain combinations, as there are several sources of power.

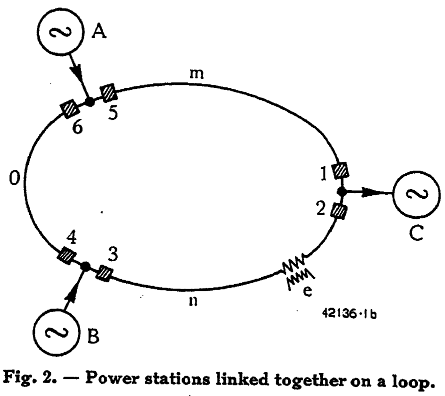


Fig. 2. — Power stations linked together on a loop.
A, B, C. Power stations.
e. Voltage of quadrature transformer.
1, 2, 3, etc. Meters.
m, n, o. Lengths of the loop.

1. As in case (a), it may happen that line n, or a transformer inserted thereon, is overloaded and that it is desirable to divert a part of the power from B over branch o-m.

2. It may also happen to be advantageous that station C should get the power from station B through the o-m branch instead of through the n branch. An auxiliary voltage e introduced allows of diverting the power delivered by B through the o-m line.

Of course, this does not alter the watt-power delivered by stations A and B which is only dictated by the opening of the turbines. If, for example, the metering rates of meter 1 are lower than those of meter 2, the consumer C now gets power at the lower metering tarif. If station A does not want to be disadvantageously affected, it must not buy the power from station B at a higher rate, through meter 6, than it sells it at to station C through meter 1. This diversion of power flow can, thus, only be allowed when station B sells power cheaper to A than to C (if, for example, A is a big power consumer). This auxiliary voltage e should be so directed that the circulation current set up by it in the loop when superimposed on the natural currents produces the desired resultant current, and it must have an angular phase advance on the auxiliary current, which is determined by the constants R and X of the loop.

3. If the loop containing several power stations is open, and if it is desired to close it, when in operation, a current surge occurs which may be very severe, due to the relative phase displacement or inequality of the voltages at both ends of the open loop. This current surge is eliminated by closing the loop by means of a quadrature regulating transformer so designed that it produces an auxiliary voltage equal and opposed to the voltage difference. This transformer also allows the loop to be opened without danger of producing oscillations in the system; it can also be used to prevent equalizing currents being set up.

(c) *The system is asymmetrically loaded* (for example by connecting up a single-phase furnace or a single-phase railway line, etc.). In this way the system formed by the three line voltages becomes asymmetrical (Fig. 3). Symmetry can be re-established, however, by using one or two series transformers.

If it be assumed, in order to give an example, that a single-phase load under p. f. = 0·86 is connected between phases R and S, it is seen that the voltage drops caused by this single-phase current i_m in the phases R and S of the generator are practic-

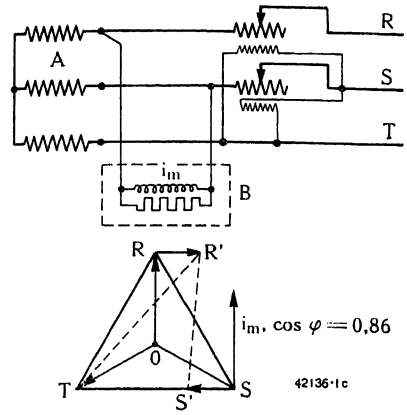


Fig. 3. — System with asymmetrical load and regulating transformer. Diagram of voltages.

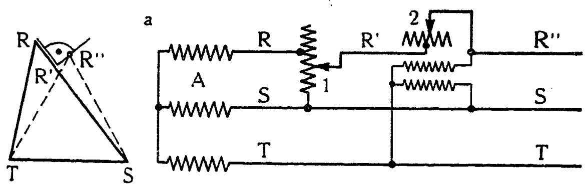
A. Alternator.
B. Single-phase load.
i_m. Current of single-phase load.
R', S', T. Voltage triangle of system after deformation due to the single-phase load.
R, S, T. Voltage triangle re-established.

ally in phase with the voltage ST or TS. This is because the current in phase R is in phase with the voltage OR and the voltage drop is, for all practical purposes, purely inductive. The remedy will, thus, be to insert on each phase R and S a series transformer excited by the voltages TS and ST. The tap changers of both transformers are governed by a regulator which equalizes the two voltages TR and TS. The auxiliary voltage delivered by these transformers will be equal and opposed to the two voltage drops to be compensated.

This solution of the problem, however, does not apply to every case as it assumes that the single-phase load is constantly connected between the same two phases, that it works under a constant p. f. and the characteristics of the current circuit in which the voltage drops occur are not altered during service. It is, however, possible to connect the transformer so that symmetry is re-established, automatically, independently of the size and distribution of the load of the individual phases or of their power factor.

To do this, an additional voltage in the direction of vector SR is created in any one phase — R, for example — by means of an auto-transformer 1, according to the diagram Fig. 4 a or by means of a series transformer 1 according to the diagram Fig. 4 b. Further, a second additional voltage in the R' R'' vector direction perpendicular to RS is created in the same phase R, by means of a series transformer 2. The regulator of transformer 1 regulates the size of RS, the point R moving along RS towards R'. The regulator of the transformer 2 regulates TR, the point R' moving on a perpendicular to SR towards R''. This perpendicular voltage is obtained by exciting the two excitation windings with which transformer 2 is provided with two voltages TR and TS.

There remains, therefore, one of the three line voltages (ST) which is not influenced by the regulation. It is an independent variable quantity. In order that, at all times, RS and TR should be maintained equal in size to this independent and variable quantity



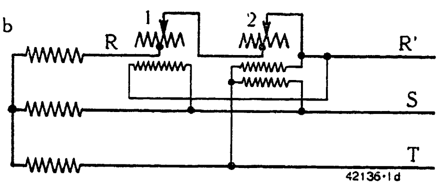


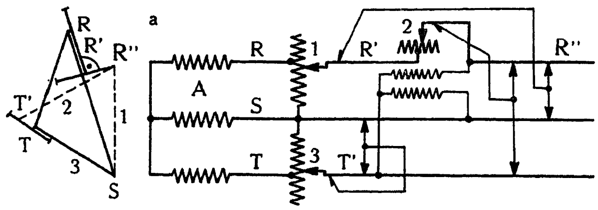
Fig. 4a. — System with asymmetrical voltage triangle and two regulating transformers.

A. Alternator.
R, S, T. Voltage triangle after deformation
R'' ST. Voltage triangle re-established.
R' S. Regulating voltage, by transformer 1.
TR''. Regulating voltage, by transformer 2.
R' R''. Additional voltage supplied by 2.
1. Regulating auto-transformer.
2. Regulating series transformer.

Fig. 4b. — Asymmetric system with two regulating transformers.
1 and 2. Series transformers.

ST (condition of the symmetry of the voltage triangle) the latter must influence, at all times, the settings of both regulators 1 and 2. This is easy to accomplish by, for example, replacing the springs of these regulators by a second moving system influenced by the voltage ST. These regulators then work as differential relays and govern the position of the tap changers of the transformers by the closing or opening of their contacts.

It should be remarked, here, that this system assures the symmetry of the voltages as two of the line voltages are constantly maintained equal to the third one, which plays the part of master voltage. It does not suffice, however, to maintain a constant voltage, as the master voltage is itself a variable quantity. If it is desired both to maintain symmetry of the voltages and a constant voltage value, a third auto or series transformer must be used. In Fig. 5 the regulators of transformers 1, 2, and 3 regulate the voltages R''S, T'R'' and ST' (they are influenced by these voltages). Connections according to 5b are equivalent to those of 5a, because the excitation voltages of the three transformers have been so chosen that the same additional voltages as in 5a are attained. This transformer 3 (Fig. 5a or 5b) regulates the size of the voltage ST' to a constant value; R''S and T'R'' are regulated by 1 and 2 to the same value. Regulators 1 and 2 do not, now, require to be influenced by ST'. It suffices to set them for the same value as 3. These are regulators of the standard type. Thanks to the use made of series transformers, that



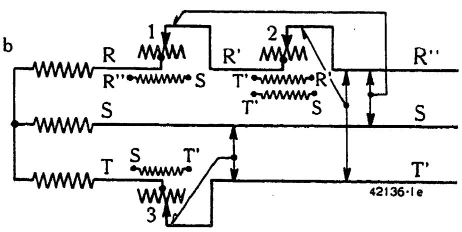


Fig. 5a. — System with asymmetrical and variable voltage triangle and three regulating transformers in two phases.

A. Alternator.
R, S, T. Voltage triangle after deformation.
R'', S, T'. Voltage triangle re-established.
R'' S. Voltage regulated by transformer 1.
T' R''. Voltage regulated by transformer 2.
R' R''. Additional voltage supplied by 2.
1, 2, 3. Auto and series regulating transformers.

Fig. 5b. — Asymmetrical system with variable voltages.

1, 2 and 3. Series-type regulating transformers.
R'' S; T' R''; T' S; ST'. Excitation voltages.

is by regulating the three voltages in two phases only, hunting is avoided. The exclusive use of auto-transformers that is regulation in the three phases does not eliminate hunting, because it displaces all three apexes of the voltage triangle, as is clearly seen from the diagram Fig. 6.

Assuming, for example, that regulator 1 works so as to correct the voltage RS it also alters, simul-

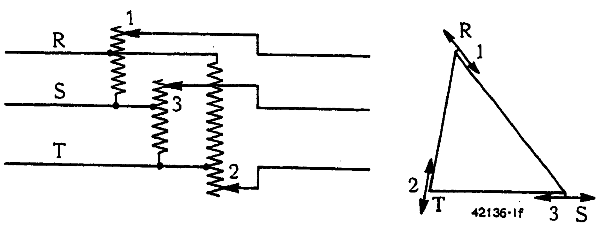


Fig. 6. — System with asymmetrical and variable triangle of voltages and three regulating transformers in the three phases.

R, S, T. Voltage triangle with additional voltages.
1, 2, 3. Regulating transformers.

taneously, the voltage TR and provokes, as a consequence, an intervention of regulator 2, which latter has a double effect:— it corrects voltage TR and, thus, also alters voltage ST, which brings regulator 3 into action, which, again, results in a reaction on regulator 1. A new cycle begins; the regulators are said to hunt. It is true that the amplitude of the voltage variation diminishes and that the hunting effects will cease when, once, the amplitude has become smaller than the sensitivity of the regulators. However, these voltage variations which take place during the time the effect is dying down, should be eliminated; if the fluctuations originating from the distribution system are frequent, they can initiate a new cycle of oscillations of the regulators as the first one is dying away, and the three voltages are kept in constant fluctuation. It would, therefore, be necessary to interlock the regulators, a complicated and delicate matter. It is obvious that a regulating system the connections of which eliminate hunting is to be given preference and this advantage is offered by the system shown in Fig. 5, which system of connections breaks the linking together of the three regulators. The conditions to be fulfilled are such that the system while regulating separately the three line voltages, that is to say having three regulators influenced each by one of the three line voltages:—

1. must not displace one end of the voltage triangle, S, for example, and
2. must displace one of the two other apexes, R, for example, by means of two distinct regulating operations, of which one must not alter the size of the voltage regulated by the other.

If Fig. 5 is studied, it is seen that, when it operates, regulator 1 occasions the intervention of 2 but that 2 does not occasion the operation of 3; the movement shown stops at 2. The same remark holds good for 3:— it affects 2 but 2 does not affect 1. Regulator 2 acts to displace point R' to R'' but does not change the size of the regulated voltage R'S regulated by 1 because, practically, the arc R'R'' with centre at S and the perpendicular to RS coincide. Thus, hunting is eliminated.

This arrangement solves, fairly simply, the double problem of the re-establishment of symmetry and of the regulation of the voltage to constant value in the asymmetrical three-phase system. The output of each transformer is equal to a determined percentage of the power passed through and this percentage is equal to the voltage variation to be compensated, also expressed in percentage.

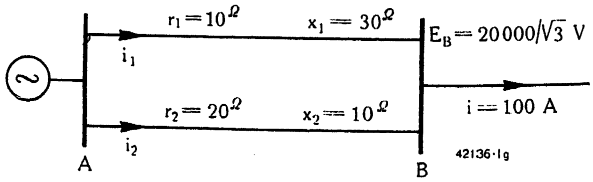


Fig. 7. — Power station supplying over two parallel lines.

A. Outgoing bus-bars.
B. Incoming bus-bars.
E_A. Phase voltage at outgoing point.
E_B. Voltage at incoming point.

Example (Fig. 7).

Let us take a concrete example of case (a) given at the beginning of this article. Intentionally, very different conditions have been assumed for r and x, for both lines, so as to accentuate the phase displacement between i_1 and i_2. The problem is to deliver 3460 kVA to B. The incoming current at that point is 100 A and the line voltage 20,000 V. To simplify the problem, the capacitance and conductance of the lines have been disregarded. To begin with, the sizes of i_1 and i_2 are determined — to this end, the impedance diagrams are formed with the known quantities r_1, x_1, z_1 and r_2, x_2, z_2 (Figs. 8a and 8b). At a suitable scale, these diagrams represent the ohmic, inductive and resultant voltage drops in lines 1 and 2. The resultant voltage drops $\triangle E_1$ and $\triangle E_2$ are really equal in size and direction and must, therefore, coincide. If the triangle of Fig. 8b is enlarged in the $\triangle E_1 / \triangle E_2$ ratio and if it is superimposed on the triangle of Fig. 8a, the diagram of Fig. 9 results in $\triangle E_1 = \triangle E_2 = \triangle E$.

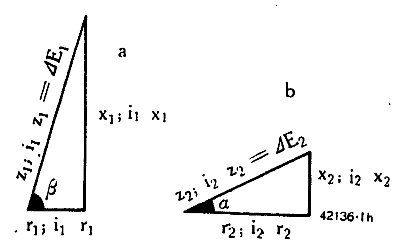


Fig. 8. — Impedance or voltage-drop diagram.

$i_1 . r_1$, $i_2 . r_2$. Ohmic voltage drop in lines 1 and 2.
$i_1 . x_1$, $i_2 . x_2$. Inductive voltage drop in lines 1 and 2.
$i_1 . z_1$; $i_2 . z_2$. Resultant voltage drop in lines 1 and 2.

This diagram gives the vectorial direction of i_1 and of i_2. The vector i_1 forms an angle β with $\triangle E$ and i_2 an angle α. On the other hand $i_1 z_1 = i_2 z_2$ so that $i_1 = \frac{z_2}{z_1} \times i_2$. Now, $z_1 = 31{\cdot}6$ ohms; $z_2 = 22{\cdot}4$ ohms (Fig. 7) and, therefore $i_1 = 0{\cdot}71\ i_2$.

The current diagram is now found, at any scale (Fig. 10). The geometric sum of i_1 and i_2 is $i = 100$ A from which:—

$i_1 = 45$ A; $i_2 = 63$ A. The angle between the current i and voltage E_B at the incoming point form an angle φ which is dictated by the nature of the consumer apparatus. The position of i in relation to E_B being determined, the current and voltage diagram can be found (Fig. 11).

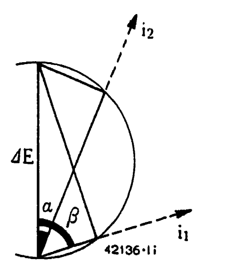


Fig. 9. — Diagram of currents:— direction of vectors.

ΔE. Resultant voltage drop of A and B.
i_1. Current in line 1.
i_2. Current in line 2.
α. Angle of impedance of line 2.
β. Angle of impedance of line 1.

If, now, it is desired to have $i_1 = i_2$ (50 A) an additional voltage will be introduced to create an additional current in the 1—2 loop, which will be MR in line 1 equal to NR in line 2 = 22·5 A (Fig. 12). The current diagram of Fig. 12 shows that the total losses in both lines are lower when $i_1 = i_2 = 50$ A than when the partition of the currents in the two lines is the natural one. This is because the sense of the natural currents are, generally, not in phase and their arithmetical sum grows with the increase of their relative displacement; this sum is at its minimum when the currents coincide. In the case under consideration, the line losses are reduced in the following proportion:—

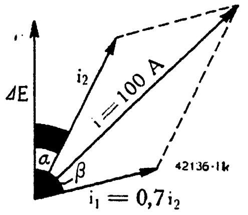


Fig. 10. — Diagram of currents:— sizes.

i_1. Current in line 1.
i_2. Current in line 2.
i. Resultant current consumed at destination point.
ΔE. Resultant voltage drop, from A to B.

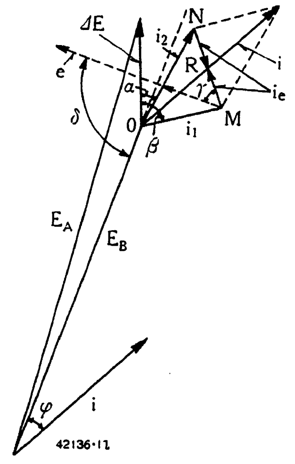


Fig. 11. — Diagram of currents and of voltages.

E_A. Phase voltage at power emitting point.
E_B. Phase voltage at consumption point.
ΔE. Voltage drop resulting, from A to B.
OM = i_1. Current in line 1.
ON = i_2. Current in line 2.
OS = i. Resultant current at consumption point.
MR. Additional current in line 1.
NR. Additional current in line 2.
OR. Resultant current in lines 1 and 2.
e. Additional voltage.
δ. Angle between additional voltage and voltage of system.

Losses without additional voltage:—

$$3 \cdot 45^2 \cdot 10 + 3 \cdot 63^2 \cdot 20 = 298{\cdot}6 \text{ kW}.$$

Losses with quadrature transformer:—

$$3 \cdot 50^2\ (10 + 20) = 225 \text{ kW}.$$

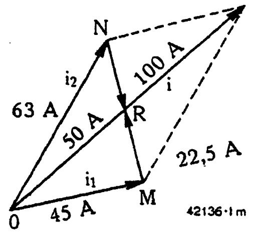


Fig. 12. — Diagram of currents:— additional currents.

Minimum losses:—

It can be presumed that currents i_1 and i_2 will be in phase, which the calculations will demonstrate. To determine their values corresponding to minimum losses, the process is as follows:—

Losses are expressed in function of i_1 and of i_2, i. e. of their ohmic and inductive components.

$$P = i_1^2 \times r_1 + i_2^2 \times r_2 = (i_{w_1}^2 + i_{b_1}^2) r_1 + (i_{w_2}^2 + i_{b_2}^2) r_2. \quad (1)$$

P is now to be determined in function of i_{w_1} and of i, so as to be able to differentiate in relation to i_{w_1}.

By making $\frac{dP}{di_{w_1}} = 0$, the value of i_{w_1} is obtained, which gives the lowest losses. To this end the Kirchhoff laws are set out for the components of the currents (Fig. 13 b)

$$i_{w_2} = i_w - i_{w_1} \qquad (2)$$

$$i_{b_2} = i_b - i_{b_1} \qquad (3)$$

Ohm's low also gives (Fig. 14)

$$i_1 \cdot \cos \varphi_1 \cdot r_1 + i_1 \cdot \sin \varphi_1 \cdot x_1 = i_2 \cdot \cos \varphi_2 \cdot r_2 + i_2 \sin \varphi_2 \cdot x_2 \qquad (4)$$

which can be expressed:—

$$i_{w_1} \cdot r_1 + i_{b_1} \cdot x_1 = i_{w_2} \cdot r_2 + i_{b_2} \cdot x_2 \qquad (4a)$$

These relations hold good whatever the p. f. of the load may be. For the sake of simplification let p. f. = 1, the result then is Fig. 13 a.

(2) and (3) become:—

$$i_{w_2} = i - i_{w_1} \qquad (2a)$$

and $i_{b_2} - i_{b_1}$ (3a)

By eliminating i_{w_2} and i_{b_2} from (4a) with the help of (2a) and (3a) the result is:—

$$i_{b_1} = \frac{i \cdot r_2 - i_{w_1} c}{d}$$

or $c = r_1 + r_2$ and

$$d = x_1 + x_2 \qquad (5)$$

By introducing (2a), (3a) and (5) into (1), P in function of i_{w_1} and of i is obtained.

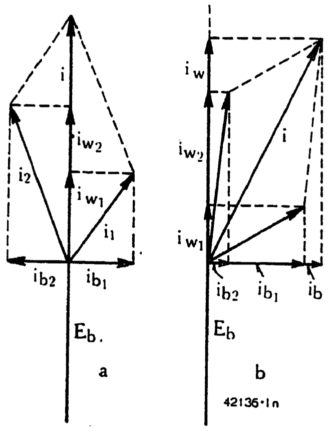


Fig. 13a. — Diagram of ohmic and inductive components of the currents, to determine the minimum losses; purely ohmic load.

E_B. Phase voltage of system at consumption point.
i. Resultant current consumed at consumption point.
i_1. Current in line 1.
i_{w_1}, i_{b_1}. Ohmic and inductive components of i_1.
i_2. Current in line 2.
i_{w_2}, i_{b_2}. Ohmic and inductive components of i_2.

Fig. 13b. — Diagram for a partly inductive load.

By differentiating, putting

$$\frac{dP}{di_{w_1}} = 0, \text{ which gives (6) } i_{w_1} = i \cdot \frac{r_2}{r_1 + r_2} \qquad (6)$$

which is the value corresponding to P min.

By substituting (6) in (5), $i_{b_1} = 0$ and therefore $i_{b_2} = 0$

$$i_{w_1} = i_1 = i \cdot \frac{r_2}{r_1 + r_2}$$

As was assumed, the currents i_1 and i_2 coincide in phase.

In the present case

$$i_1 = 100 \times \frac{20}{30} = 66{\cdot}6 \text{ A and } i_2 = 33{\cdot}3 \text{ A.}$$

$$P = 3 \cdot 66{\cdot}6^2 \cdot 10 + 3 \cdot 33{\cdot}3^2 \cdot 20 = \underline{200 \text{ kW.}}$$

The additional current required will be

$$MR = -NP = 33{\cdot}5 \text{ A (Fig. 15).}$$

The direction of current vector MR being known, the value of the additional voltage e can be deduced therefrom; it will be displaced forward as regards the current vector by an angle γ determined by

$$(r_1 + r_2) \text{ and } (x_1 + x_2) \text{ (Fig. 16).}$$

II. DETERMINATION OF THE REGULATING QUADRATURE TRANSFORMER.

The size of the additional voltage is equal to

$$i_{add.} \cdot \sqrt{(r_1 + r_2)^2 + (x_1 + x_2)^2}$$

$$= 22{\cdot}5 \cdot \sqrt{30^2 + 40^2} = 22{\cdot}5 \times 50 = 1125 \text{ V/ph.}$$

The transformer is, therefore, a series transformer to be dimensioned for an additional phase voltage of 1125 V. A line voltage excitation of 20,000 V and a current of 50 A. Its proper output will be $3 \times 1{\cdot}125$ kV $\cdot$ 50 A = 170 kVA and the output passing through it will be $50 \cdot 20 \cdot \sqrt{3} = 1730$ kVA.

As regards the angle of phase deviation of the additional voltage with regard to the phase tension of the system, it does not differ, in practice, much from 90°. This is because, usually, the necessary additional current is not far from being in phase with the system voltage (see Fig. 15) and because the system made up of a loop of lines, in which this current has to circulate, is generally an inductive one (either because r of the line itself is small as compared to x, or because there is a transformer somewhere on the loop).

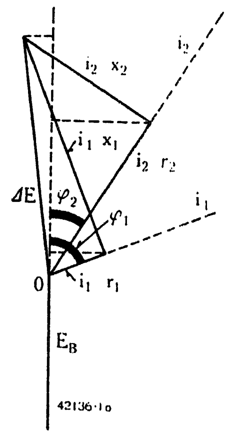


Fig. 14. — Diagram of voltage drops and of their projections on the voltage of the system.

E_B. Phase voltage of system at consumption point.
i_1. Current in line 1.
i_2. Current in line 2.
φ_1, φ_2. Angles of currents i_1 and i_2 with system voltage.
$i_1 r_1$, $i_2 r_2$. Ohmic voltage drops in lines 1 and 2.
$i_1 x_1$, $i_2 x_2$. Inductive voltage drops in lines 1 and 2.
$i_1 Z_1$, $i_2 Z_2$. Resultant voltage drops in lines 1 and 2.

This is the reason why the regulating transformer is generally designed to introduce an additional voltage perpendicular to the phase voltage of the system and from this comes the designation:— "quadrature transformer".

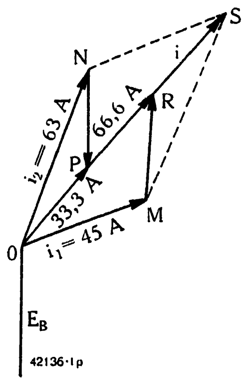


Fig. 15. — Diagram of currents:— additional currents giving minimum losses.

- E_B. Phase voltage at consumption point.
- OS = i. Resultant current consumed at consumption point.
- OM = i_1. Current in line 1.
- MR. Additional current in line 1.
- OR. Resultant current in line 1.
- ON. Current in line 2.
- NP. Additional current in line 2.
- OP. Resultant current in line 2.

It is, however, possible to attain any angle δ between 0 and 360^0 by proper connections of the transformer, two excitation windings per phase being used, if necessary.

III. CONNECTION OF THE REGULATING QUADRATURE TRANSFORMER.

(a) *Without excitation transformer* for medium system voltages. In order to attain $\delta = \pm 90^0$, it is sufficient to excite phase R by means of voltage TS or ST, S by means of RT or TR, T by means of SR or RS. Connections will, therefore, be according to the diagram as shown in Fig. 17. The diagram of Fig. 18 shows how any angle desired can be attained.

Vector OR represents the phase voltage and the various vectors RA, RB, RC, etc. the additional voltages reached by exciting the transformer by the various available voltages (ST, RT + ST) etc. If, when exciting by means of two windings, for example by RT + ST, the same number of turns is given to both windings, the additional voltage attained will be in one determined direction only, but, by varying the number of turns, any sense can be obtained between $\pm 30^0$ of the first one. This is, therefore, a means which when added to the reversal of connections on the excitation windings allows of reaching any angle δ between 0 and 360^0.

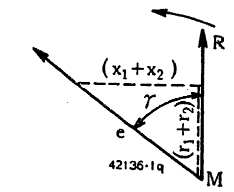


Fig. 16. — Diagram giving direction of additional voltage vector as referred to additional current.

- e. Additional voltage.
- MR. Additional current.
- $r_1 + r_2$. Total resistance of loop.
- $x_1 + x_2$. Total reactance of loop.
- γ. Angle of loop impedance = angle between current and additional voltage.

(b) *With excitation transformer,* for high system voltages $\delta = 90^0$ is obtained by coupling the excitation transformer △/人. In this way the three line voltages of the system are obtained, as regards the position of the vectors, on the secondary side (Fig. 19). By coupling it 人/人, the three phase voltages are obtained as regards position of vectors. This suffices, along with reversal of connections, for getting all values, for δ, between 0 and 360^0 in steps of 30^0 to 30^0 (Fig. 20).

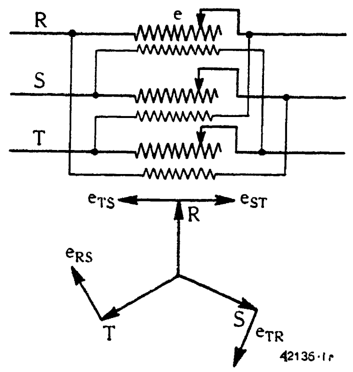


Fig. 17. — Connections of quadrature transformer inserted straight into system. Diagram of system and additional voltages.

- R, S, T. Phase voltages of system.
- e. Additional voltage.
- $e_{ST} = -e_{TS}$. Additional voltages in phase R.
- e_{TR}, e_{RS}. Additional voltages in phases S and T.

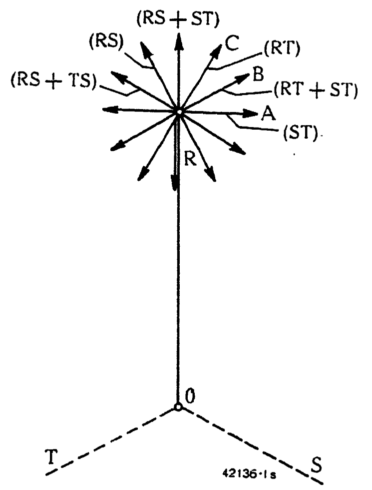


Fig. 18. — Diagram of additional voltages, forming an angle, of any value, with the voltage of the system.

- R, S, T. Phase voltages of system.
- RA, RB, RC. Additional voltages.
- (ST), (RT + ST). . . . = Excitation voltages.

If an intermediary value is required, it is necessary to place two excitation windings on the series transformer, each of which is fed by a phase voltage (excitation transformer connected 人/人); the ratio of turns of the said windings being suitably chosen.

If, for example, $\delta = 100^0$ is required, phase R, for example, of the series transformer is excited by means of two phase voltages TO and OS, the number of turns of the TO winding being x and that of the OS winding 0·57 x (Fig. 21). If the resultant excitation voltage is represented by 100 %, the component TO will be, approximately 73 % and OS 41 %.

The design of the regulating quadrature transformer and the arrangement of the windings do not

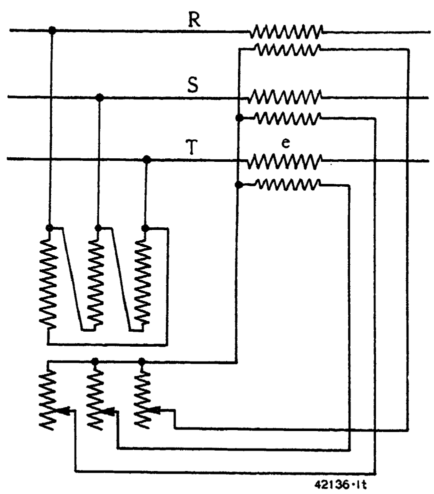


Fig. 19. — Connections of quadrature transformer with excitation transformer.

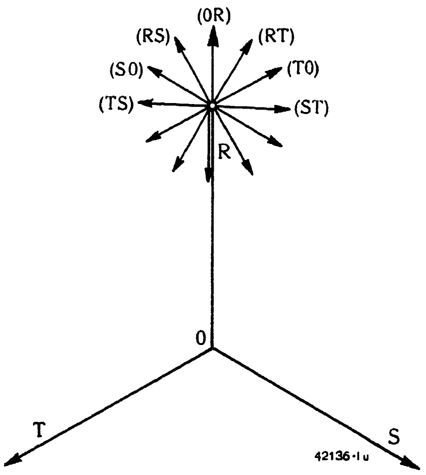


Fig. 20. — Diagram of additional voltages, forming an angle from 0 to 360°, in steps of 30°, with the voltage of the system.

R, S, T. Phase voltages of system.
(ST). Composed excitation voltage.
(TO). Simple excitation voltage.

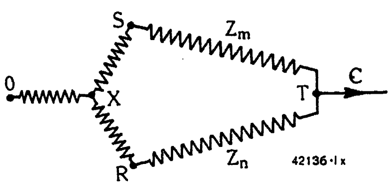


Fig. 23. — Diagram, equivalent to that of Fig. 22.

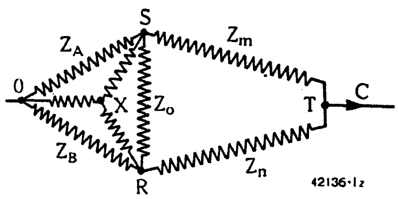


Fig. 24. — Diagram of Fig. 23, transformed.

differ from those of an ordinary regulating transformer with taps and a step type of tap changer.

The case just studied belongs to the typical a type but there are no difficulties in obtaining the same results for an example of b type. This latter can be brought into line with class a in the following way:—

The power stations A and B as well as the lines are replaced by equivalent impedances. The following paragraphs explain the method followed to determine the impedances. In reality however, r and x are determined separately, but the method is the same. The values of the impedances of the power stations to be put in the new diagram are determined by the current that each power station has to supply to the consumer.

Let I_A be the current station C desires to get from power station A and let I_B be that from power station B.

$$Z_A = \frac{E\ ph}{I_A};$$

$$ZB : \frac{E\ ph}{I_B}$$

This leads to the diagram given in Fig. 22. The neutral points O_A and O_B of the alternators can be connected which leads to Fig. 23. The triangle OSR can be replaced by the corresponding star inscribed, the branches of which can be ascertained by means of the following equations:—

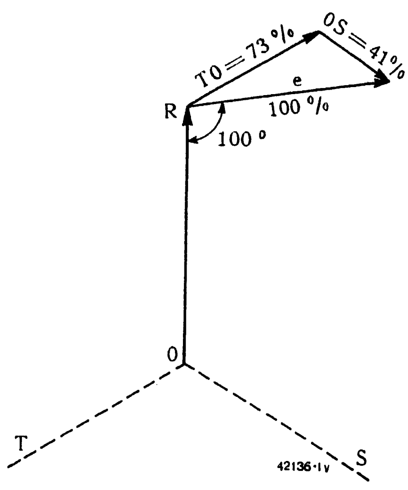


Fig. 21. — Diagram of additional voltages obtained by double excitation winding and forming an angle with the voltage of the system of any value from 0 to 30°.

R, S, T. Phase voltages of system.
TO. Excitation voltage (fraction of simple voltage) on one of the windings.
OS. Excitation voltage (fraction of simple voltage) on the second winding.
e. Resultant excitation voltage.

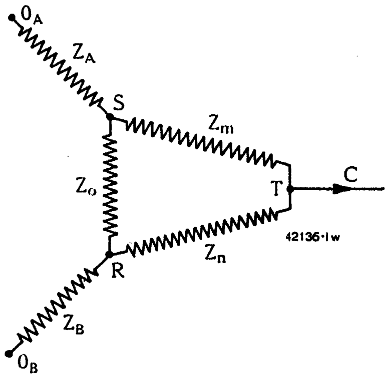


Fig. 22. — Power stations linked by a loop:— equivalent diagram.

$O_A = O_B$. Power station.
C. Consumer.
Z_A, Z_B. Equivalent impedances to power stations.
Z_o, Z_m, Z_n. Equivalent impedances to lengths of loop.

$$XO = \frac{Z_A \times Z_B}{Z_A + Z_B + Z_O};\quad XS = \frac{Z_A \times Z_O}{Z_A + Z_B + Z_O};$$

$$XR \frac{Z_B \times Z_O}{Z_A + Z_B + Z_O}$$

This gives the diagram of Fig. 24 with the impedances of each line section; this corresponds to the type a case; the triangle is drawn as in the preceding case.

(MS 956) *A. Maret. (Mo.)*

Owing to a printing error, the diagrams of Figs. 23 and 24 should be interchanged.

STARTING SYNCHRONOUS MACHINES BY MEANS OF MUTATORS WITH SPECIAL REFERENCE TO TURBO-GENERATORS USED AS PHASE ADVANCERS.

Decimal index 621.316.717 : 621.313.32.

IT is frequently advantageous to make use of turbo-generators, which are lying idle for long periods, in order to cover the wattless load on a system. This is particularly the case in steam stand-by and emergency stations. These plants are especially suitable for power-factor improvement, being located in towns and industrial centres, that is to say in the neighbourhood of the centre of power consumption, instead of being situated far away, as is generally the case with hydro-electric plants. Thus, while improving the power factor, they reduce the losses in the transmission line. It also happens, however, in standard steam power stations working under continuous load, that conditions are such as to make it desirable to use turbo-generators as phase advancers. It often happens, at periods of low-load that the poor power factor reduces the loading capacity of the turbo-sets to such an extent that it becomes necessary to maintain a greater number of such units running than would be justified by the watt load being distributed. If, now, in cases like this, one or several generators can be uncoupled from their respective turbines and run purely as a phase advancer, it is possible to eliminate the no-load losses in the turbines belonging to them and, further, to increase the useful load of the other units considerably, i. e. to run the latter under much better conditions of efficiency. If, in spite of the advantages just set out, the running of turbo-generators as phase advancers is a practice which is seldom resorted to, the reason — however strange it may seem at first glance — is that none of the devices available up-to-date to start and bring up turbo-generators to synchronous speed have proved satisfactory.

Of the various starting methods, the most obvious is the running up of the generator along with its turbine. As, however, there are no couplings available which can be loosened in service at such high speeds and outputs as those standard for turbo-sets, it is necessary to allow the turbine to continue running under no load, after synchronism is reached, which means considerable losses incurred even although the condensing plant is kept working so as to reduce friction and windage in the blading. An essential condition for this starting method is, of course, that a head of steam be available, i. e. that the boilers be under pressure, which is, precisely, not the case in stand-by or emergency stations at those periods during which the generators in the said stations would be available to take over wattless load. To this must be added that, in order to keep up the vacuum for the whole time of operation, there must be sealing steam available for the sealing shaft glands. Further, a set run in this way calls for the same supervision as a set under load, because the condensing-plant pumps have got to be kept running, as well.

Asynchronous starting up is another method, the generator being uncoupled from its turbine and supplied with current from the system, through a starting transformer. The heavy current surge which is necessary, here, in order to get the rotor revolving is one of the disadvantages of this solution. This is not only an unwelcome phenomenon for the supply system but is a real danger to the generator itself. A damping winding built in does something to alleviate this trouble, but this cannot be used on an existing generator unless one is prepared to concede a considerable reduction in the output of the machine. In a new machine to be built, the addition of a damping winding of this kind either means a reduction in the rated output of the type of generator under consideration or else leads to taking a bigger type of machine than would otherwise be necessary.

Synchronous starting up (running up with a second machine) assumes that there is another set of the same output which is also idle and that a boiler is also in service at the same time, to deliver the steam required to put the second set into service. When these conditions are fulfilled, the two generators — the one to give wattless load which is uncoupled from its turbine and the generator of the starting set — are electrically coupled and are then brought up to speed, together, by the turbine. Apart from the fact that the requisite conditions described are, usually, not fulfilled, this process which has, otherwise, no technical drawbacks, has the disadvantage of taking up much time as it entails starting a whole turbo-set with all its accessories.

The most suitable of the starting processes generally used up till now, is that with a starting motor. An ordinary induction motor can be used when the generator being started has, at least, four poles; it is necessary that the number of poles of the induction starting motor should be smaller than that of the synchronous generator which is being started, as this is an essential condition for bringing up the latter machine to synchronous speed. In synchronizing, the synchronous speed is somewhat exceeded and, while the speed is being slowly lowered, the line breaker

is closed, at the proper moment. Obviously, this process cannot be applied to two-pole synchronous generators, that is to say to the standard turbo-generators; in this case an induction motor which can be synchronized must be used. The start and subsequent acceleration is carried out, in the usual way, by cutting out the resistances in the rotor circuit, step by step. Later D. C. is applied to the rotor winding of the motor, during which the synchronous speed is attained. This starting method, as well, has serious drawbacks. If the starting motor is placed between the generator and the exciter, it must run continually, even when the generator is operating normally, that is to say as a power producer. The windage losses caused by the motor are, obviously, detrimental. If, now, it is desired to mount the motor on the end of the set, the shaft of the small exciter must be made strong enough to transmit the motor torque. This leads to quite special designs of the exciter armature and of its commutator. For this reason, direct coupling of the generator exciter cannot be used, the latter being then driven by a separate electric motor. Generally, the reason why the solution of the problem by means of a starting motor is not applied is want of space to lodge the said motor, this owing to the fact that the phase-advancing problem generally comes to the fore after the plant is already built.

Brown Boveri have now succeeded in finding a starting device, making use of mutators, which meets all the requirements of the case.

The new process, described in the following paragraphs, is suitable for every kind of synchronous machine and is especially useful for starting turbo-generators. It eliminates all the weaknesses of the other starting methods already mentioned and has the additional advantage of allowing the successive starting of any number of synchronous machines with the help of a single starting equipment.

A few general remarks should precede the description proper. As is well known, it is possible to retard the moment of ignition of the anodes of a mutator by means of anode grids, and to have the said ignition occur at any moment desired on the A. C. curve and even to suppress ignition altogether. If, for example, the grid is negatively charged, the arc which should ignite at each cycle does not start up again as it would otherwise do. If, now, the grid which has been first charged negatively is given a positive charge, ignition of the arc takes place immediately, on condition that the positive charge is imparted to the grid during the time the anode voltage is positive, i. e. during the half cycle in which the passage of a current is possible. By using a suitable grid control, it is possible to dictate the moment of ignition regularly and at the moment when the A. C. voltage attains a given value. If the moment of ignition is displaced, the duration and magnitude of the individual current waves can be regulated over a wide range. Fig. 1 shows how the R. M. S. value of the D. C. voltage can be altered, in mutating a single-phase A. C. current, by displacing the moment of ignition. The diagram of Fig. 2 will now make it clear how this property can be applied to the starting of synchronous machines. The distributor 7, termed "system distributor", which is a contacting apparatus driven by a small synchronous motor and which rotates in synchronism with the frequency of the system, imparts, successively and at intervals of a whole cycle, a positive voltage impulse of a half-cycle duration, to each negatively-changed anode grid of the mutator.

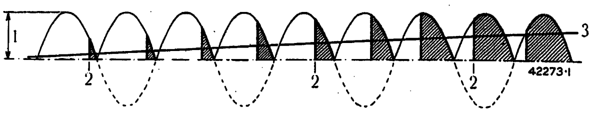


Fig. 1. — Diagram of voltage regulation when a grid-controlled mutator is used.

1. Maximum value of A. C. voltage. 2. Moment of arc ignition. 3. R. M. S. value of D. C. voltage.

The relative position of the brushes and contact segments of the distributor are so chosen that these positive impulses always occur during those half cycles during which the voltage of the anodes concerned are positive. The beginning of the current wave, however, can be made to vary between the limits of this half cycle by making a corresponding displacement of the brushes. In this way, a voltage regulation on the D. C. side of the mutator is attained such as is shown in principle in Fig. 1. The D. C. necessary for grid control is delivered by a small D. C. source, not shown in the diagram. As the latter shows, the positive lead of this D. C. source is carried to a distributor 9 termed "motor distributor" through a further contact maker and the grids can only get the positive charges of distributor 7 if the motor distributor makes connection with the source of current. The motor distributor is a controlling apparatus the rotating part of which is mounted on the shaft of the rotor of the synchronous machine being started up. The contact segment establishes a connection with one of the three contact makers of the system distributor according to the angular position of the rotor, through one of the three brushes which are at an angular displacement of 120° from each other.

The cathode of the mutator is connected to the neutral point of the stator winding. The smoothing choke coil 10 damps down the pulsations in the D. C. Each of the three pairs of anodes is connected through the respective transformer windings with an end of the stator winding 2 of the synchronous machine to be started (to make the diagram clearer, only two

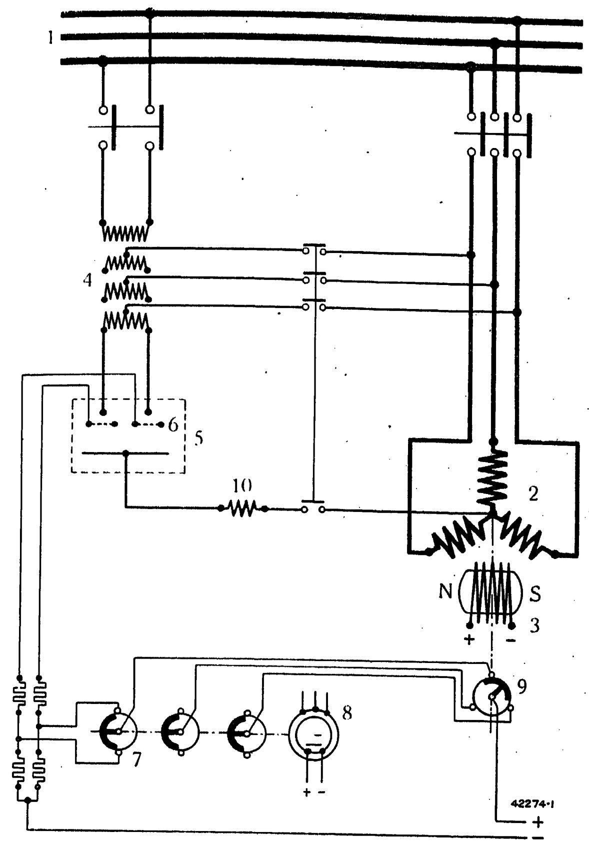


Fig. 2. — Diagram of the starting equipment of a synchronous generator with the help of a mutator.

1, System.
2. Stator winding of synchronous machine to be started.
3. Rotor winding of same.
4. Transformer.
5. Mutator.
6. Grid.
7. System distributor.
8. Synchronous motor of system distributor.
9. Motor distributor.
10. Smoothing choke coil.

mutator anodes with the leads belonging thereto are shown). As, under ordinary conditions, the motor distributor only opens the way for the positive grid charge of a single pair of anodes at a given moment, there is only D. C. flowing in one of the three phases for a given position of the rotor while the other two phases are dead. Allowing for proper brush adjustment on the motor distributor, a field is generated in this way which produces a torque in the desired sense, in conjunction with the D. C. poles of the rotor. This causes the rotor to rotate carrying the segment of the motor distributor with it. When the rotor has passed through a certain angle, the next brush of the motor distributor gives positive current to the grids governing the next phase. While this next phase is under current and generating a field displaced by the corresponding angle forward as regards the former one, the first phase is without current. This alternance goes on repeating itself and accelerates the rotor. The magnitude of the acceleration, all other conditions being equal, depends on the mutator voltage, on the speed — counter E. M. F. of stator winding — and on the current in the rotor. As the speed increases, the counter E. M. F. increases; it is, therefore, necessary to increase the mutator voltage gradually, in order to continue accelerating the rotor. This is done by displacing the brushes of the system distributor 7 in counter sense to that of rotation (Fig. 1). This is carried out by means of a small auxiliary motor which is controlled, along with the rest of the apparatus, from the switchboard. Synchronizing and paralleling of the synchronous machine is effected, in the ordinary way, by hand or by means of an automatic paralleling device, if such is available. An interlock on the breaker causes the mutator to be automatically cut off from the stator winding when the stator breaker is closed. The rotor current of the machine being synchronized is so adjusted from the beginning that the stator winding is subjected to the exact system voltage when full speed is attained, which result is easily reached by a single test. When the synchronous machine works with a direct-coupled exciter, as is usually the case, an independent D. C. source of current is required at starting. If there is none available, a small converter set will have to be supplied, as well. This can be started up and cut out along with the system distributor 7. The output of this converter set is about 10% of that of an ordinary exciter.

As, contrary to other starting devices, the present arrangement does not absorb power uselessly, the power tapped from the system is extremely low. This means that the dimensions of the apparatus are small. The whole gear, which, as said before, can be used to start any number of machines, can easily be lodged in an adjacent chamber or in the switchgear plant. It can be controlled from the main switchboard, if so desired, as can also changing over to the various machines to be synchronized, as well. No alterations need be made to the machines, apart from fastening on the motor distributor, a very small apparatus easily secured to the built-on exciter. After synchronizing has been accomplished, the contact brushes of the distributor can be raised to save them from wear.

In the diagram of Fig. 2, the starting gear is connected up to the supply system of the synchronous machine. It may be of interest to mention that the power required for starting may be taken from another system, the voltage and frequency of which do not coincide with those of the machine being started.

Starting synchronous machines in the manner described is an application of the grid controlled mutator, and a Brown Boveri invention protected by German patent No. 501,402. This important invention has also been patented in other countries.

(MS 990) *H. Keller. (Mo.)*

NOTES.

Automatic stand-by Diesel-electric sets.

Decimal index 621. 311. 18.

THERE are public and private services which are obliged to take measures of protection against interruption of power supply and this even in cases where trouble is infrequent. The chief of these services are railway stations, post and telegraph buildings, theatres, cinemas, banks, warehouses, assembly rooms, workshops, power stations and hospitals. For all these institutions even a current breakdown of short duration may have serious disadvantages.

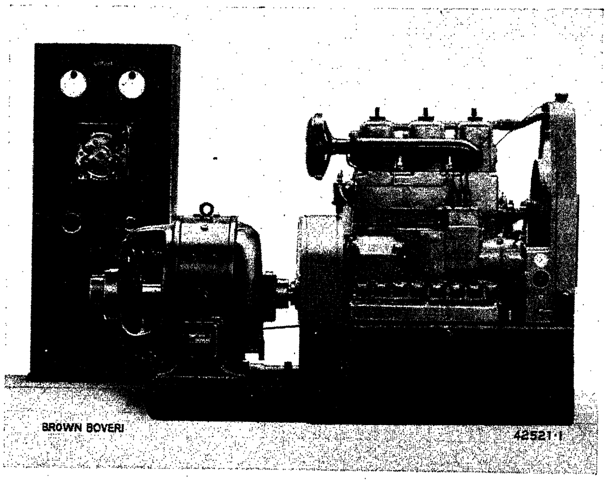


Fig. 1. — Diesel-electric stand-by set with switchgear cubicle.

For this reason, consciencious officials and business managers give all due attention to the question of an emergency-power supply.

Recent developments have shown that the former storage battery, so universally used as an emergency source of power, is being ousted from the field by stand-by Diesel sets. The main advantages of the latter are their low purchasing cost, the little room they take up, the excellent efficiency they work under, and their ability to give constant full load for as long as may be required of them. A special advantage is that not only D. C. but three-phase A. C. can be generated by a Diesel-electric set, so that, in case of trouble, the same kind of current is available as under normal conditions. Diesel-electric emergency sets can quite well be lodged in the cellar; there is no danger of fire as oil, as opposed to petrol, does not explode.

An essential condition for this successful invasion of a field belonging to the storage battery, was the possibility of obtaining on the market fast-running Diesel engines and the perfecting of automaticity in starting and stopping. Immediately the supply-system current fails, the emergency set must start up automatically. The starting apparatus used can be of many different types and it changes with the firm building the Diesel and the power of the latter.

The design of the starting equipment depends on whether the Diesel engine is to be started by a starting motor or by compressed air, it also depends on the auxiliary ignition device used (incandescent spirals or auto-igniting glow paper which becomes incandescent under the influence of compression heat, or else no auxiliary ignition device at all). There are also differences in the cooling conditions and fuel supply of Diesel engines. Owing to the variety of Diesel-engine designs, it is impossible to design a uniform starting apparatus, so that the conditions of each special case must be studied.

Apart from the secondary starting functions just mentioned the switching operations are uniform. As soon as some trouble occurs in current distribution the consumer system is automatically cut off from the supply system and the emergency set started up, automatically. As soon as the set has attained its rated speed and the generator voltage been regulated to the required value by the automatic voltage regulator, the consumer system is connected up to the stand-by generator. After the trouble has been eliminated the consumer system is automatically reconnected to the supply system and the stand-by set automatically stopped. The readiness for service of the stand-by set can be tested, from time to time, by means of a simple change-over device. Lack of fuel or of cooling water are made known, in time, by an alarm signal.

Brown Boveri are in a position to supply all the most suitable automatic apparatus for these emergency plants, using for the purpose the apparatus they have tried out in numerous types of automatic power stations equipped by them and which have worked in the most satisfactory manner.

(MS 985) *W. Kissling. (Mo.)*

Service reliability of Brown Boveri Material.

Decimal index 6 (009. 2): 621. 313. 3.

THE Manufattura Festi Rasini spinning and weaving mill, in Milan, have three Brown Boveri generators running in their Pirapola and Groppino power stations (Villa d'Ogna plant in Valle Seriana, Bergamo) which were delivered in the years 1899 and 1903. These units have run, practically, without a stop since they were put in. These are three-phase A. C. generators of the well-known WA 7/20 type each built for 235 kVA, 3150 V, 43·5 A, 300 r. p. m., 50 cycles. They are of the two-bearing design with horizontal shaft and built-on exciter and are driven by water turbines. The illustration shows one of the three alternators.

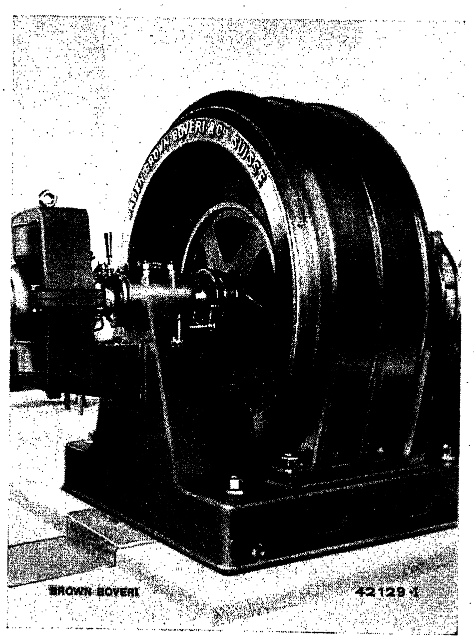


Fig. 1. — Three-phase A. C. generator 235 kVA, 3150 V, 43·5 A, 300 r.p.m., 50 cycles, delivered in the year 1899.

This plant also has 14 Brown Boveri motors running, for a total output of 600 kW, all of which date from the year 1905 and have, thus, seen 30 years of service. Although running under heavy load conditions, these motors have required none but the most trifling repairs in all that time.

(MS 949) *Prop.*

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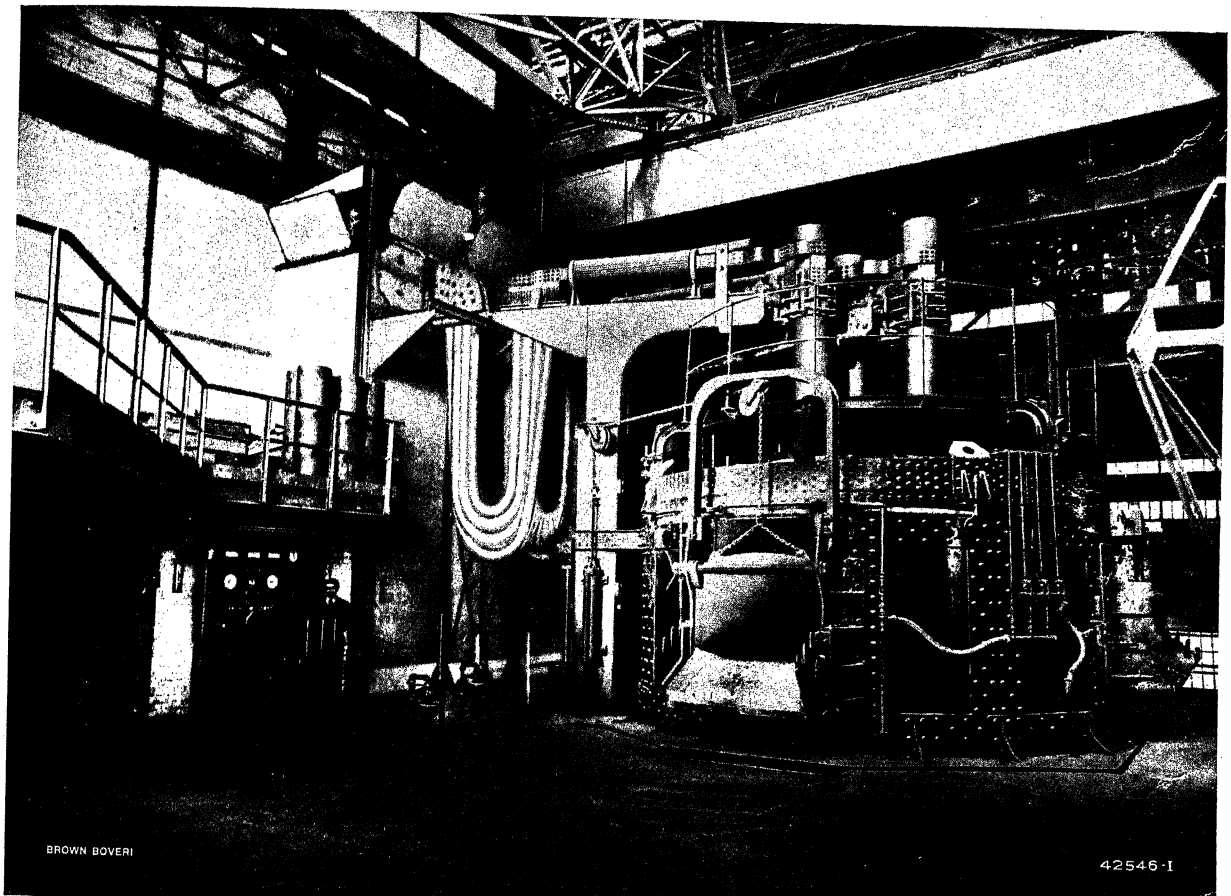

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THE BROWN BOVERI REVIEW

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THE BROWN BOVERI REMOTE-CONTROL SYSTEM.

Decimal index 621.398.

I. INTRODUCTION.

THE linking-up of large power stations supplying extensive distribution networks, so generally practiced, to-day, created a demand for contrivances for signal transmission, remote metering and remote control. Considerable progress has been made in such systems, during recent years. Not only have the existing systems been improved upon, but fundamentally new methods have been introduced. The requirements imposed upon the remote control systems have also been considerably increased. To-day one expects the system and the apparatus to fulfil the requirements of not only heavy-current engineering, but also those of communication engineering. Brown Boveri have contributed their share towards solving this none-too-easy problem and, as a result of many years' research work, have developed systems which meet the highest service requirements. A brief description of the said systems is given in the following paragraphs.

II. GENERAL PRINCIPLES OF REMOTE CONTROL.

The remote control equipment is used not only for the control of heavy-current apparatus at distant points, but also for signalling back that the control operation has been carried out and often, also, for announcing other occurrences in the plant under supervision, such as the acting of alarm signals and the tripping of protective relays. In principle, there is no difference between control and return signals. In both cases it is the duty of the remote-switching system, by closing a circuit at the emitting end, to select a corresponding circuit at the receiving end from a number of such circuits available. As a rule, there is only one pair of pilot wires available to connect the sending and receiving stations. Systems which require several pilot lines are prohibitive in cost. The process of transmission, the fundamental working principle of which is most commonly applied, consists of automatic switching over of the pilot line from one sender-receiver set to the next.

Rotating selectors are generally used, as a change-over device, which move forward synchronously, step by step. Fig. 1 shows the fundamental connections of such a selector device. The selector moves only when a control order or return signal is to be transmitted. The use of the rotating selector is almost universal in practice, although the same object can be attained by other methods, as, for instance, with

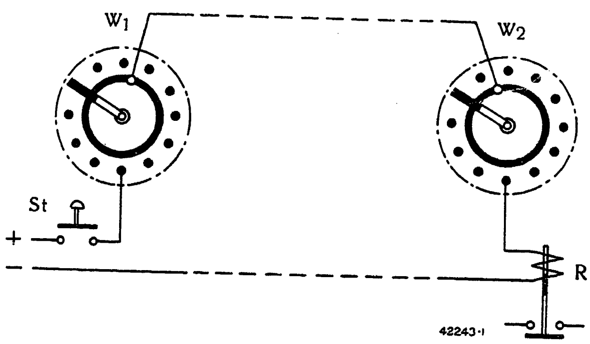


Fig. 1. — Fundamental design of a remote-control equipment with rotating selectors built to the single impulse principle.

R. Individual receiving relay. W_1. Selector of emitting station.
S_t. Control switch. W_2. Selector of receiving station.

the help of a chain of relays. From the beginning, Brown Boveri has based their methods of construction on the rotating-selector principle, a choice which subsequent research has proved to be correct. Fig. 2 shows an apparatus with moving selector, built in the year 1925.

The simple process of connecting the sending and receiving circuits, which are related, over the common pilot lines, had to be perfected when it became necessary to make use of

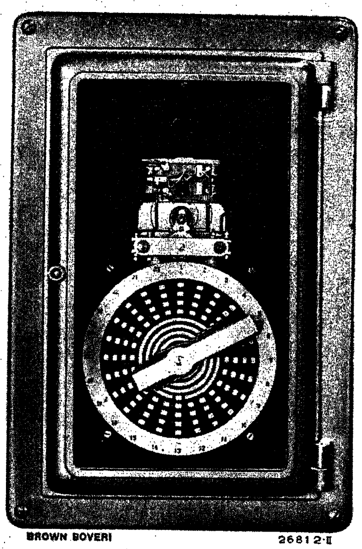


Fig. 2. — Remote-control apparatus with rotating selector, moving round when an operation is to take place, built in 1925.

pilot leads which were subject to external troubles caused by induction phenomena. If a current, which has not been generated at the sending end appears in the pilot line, no gear should be used which is based on the principle that a single impulse suffices to actuate a controlling or signalling apparatus at the receiving end. The disturbances caused by induction from external sources can only be eliminated by introducing an arrangement by which the operation of the control and signalling apparatus require a complete series of impulses and not just one impulse. In so doing, the number and duration of individual impulses as well as the intermediate pauses between them are automatically checked. Thus, if the series of impulses coming in show any irregularity, they remain ineffective on the apparatus. This improved arrangement of the remote-control system can also be carried out while retaining the fundamental principle of remote change-over switching through the agency of a rotating selector, as shown in Fig. 3.

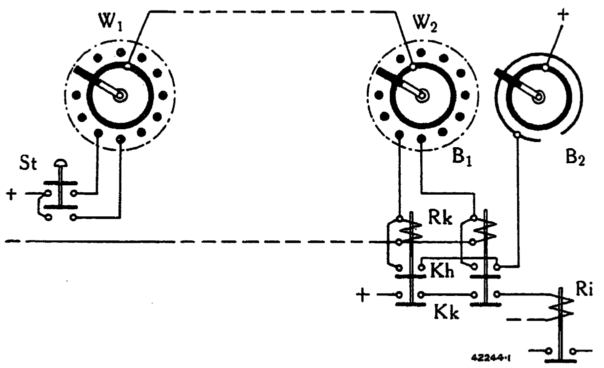


Fig. 3. — Fundamental design of a remote-control equipment built to the coded impulse principle with a pair of rotating selectors.

B_1. Selector track for excitation of the combination relays.
B_2. Selector track for the holding circuits of the combination relays.
K_h. Holding contacts.
K_k. Combination contacts.
R_i. Individual receiver relay.
R_k. Combination relay.
S_t. Control relay.
W_1. Selector in emitting station.
W_2. Selector in receiving station.

As already mentioned, the remote-control equipment is used to-day for various purposes, so that the design must cover a very wide field. The simplest case is when a small automatically-controlled plant is to be controlled and supervised from the next attended station. As a rule, the pilot or control line is formed of one pair of long distance telephone cable wires, the said cable belonging to the power plant itself or to a public telephone network. The remote control system has not to handle a particularly large number of signals, in the case under consideration and no high demands are made, here, on the speed of signal transmission. Besides, the cable connection allows of taking advantage of direct-current transmission and it is not necessary to reckon with service failures on the pilot line. The working conditions of the remote control system are, thus, relatively simple and can be fulfilled by means of inexpensive equipment. At the other extreme, is the case of the supervision of stations belonging to complete distribution networks. Here the remote control or remote signalling arrangement is an important part of the technical equipment for the load dispatcher of the whole service. In this case, one demands of the remote-control apparatus the transmission of hundreds of different signals, whereby the speed of transmission must be as high as possible. Above all, there are often big distances to bridge over, so that one has to have recourse, from an economic point of view, to signal transmission by high-frequency currents or other means which may be subject to transient disturbances. The remote control plant has thus to satisfy the highest demands imaginable as regards capacity and reliability of service.

Brown Boveri has, therefore, developed their designs in two directions. In order to meet all conceivable demands, a remote control equipment of the coded impulse system has been worked out. At the same time, for cases working under less difficult conditions, especially for the remote control of individual small plants, they have retained a very simple and easily supervised construction according to the well tried-out-method of direct pilot line switching, that is a system according to the single impulse process. For both methods of construction, fundamentally, the same type of switching apparatus and also, as far as possible, the same individual relay circuits have been used. They can only be distinguished from one another by the fact that the set of relays for the formation and dissolution of impulse codes is not found in the single impulse system and also that the method of moving the selector differs. A summary of working methods of both arrangements is given in the next paragraphs.

III. THE DESIGN ACCORDING TO THE SINGLE IMPULSE SYSTEM.

A characteristic of the single impulse process is that every control and every return signal corresponds to a special switching position of the rotary selector. Since that process does not protect against normal service line failures, it should only be used for installations with pilot lines laid in cables. In this case an impulse transmission by means of direct current is allowable, whereby the number of signals, through using polarized receivers, can be doubled. The control and signal impulses are made use of at the same time for the synchronous step-by-step movement of both selectors. At the initiation of

a signal, not only will the impulse corresponding to this signal be sent out, but the positions of all control- and signal-contacts will be passed over and touched, whereby in every position of the selector an impulse is transmitted, which moves the selector by one step forward. The polarity of the impulse will be decided by the position of the corresponding control or signal switch. The moving-on of the selector is effected independently of the polarity while the corresponding receiving organ (control or position signalling relay) will be brought to the position corresponding to the polarity of the impulse. By changing over a control switch, or by an automatic changing of position of a supervised organ, the selector, which otherwise remains in the rest position, is caused to make a complete rotation. The synchronous running of the selectors is assured by there being alternate control and signal positions along their periphery. In the control positions, the feeding of the pilot-lead takes place from the control station and in the signal positions, on the other hand, it takes place from the remotely controlled station. Thus, the step-by-step movement depends on one selector being in the sending position and the other selector in the corresponding receiving position. Should the two selectors fall out of step, due to some disturbance, the mutual switching-on movement is stopped, since both apparatus simultaneously come in a receiving position from which no further switching current impulse is transmitted. This causes a time-relay to begin to function in both stations, which cuts off all receiving apparatus from the source of current and switches over the selector drive to a local automatic breaker. The pilot lead can then be put under tension by actuating a push-button switch, upon which both selectors move towards their respective rest positions independently of one another. It must also be mentioned that not all control and signal relays need be constructed as polarized apparatus. They are then not actuated by the remote transmission impulse itself, but by the insertion of a common polarized impulse receiver, the said relays being energized from a local source of current. This indirect connection system of the reception apparatus has also the advantage that, in spite of a stronger construction of the switching apparatus, a pilot line of smaller transmission capacity, for instance, a long telephone line of small section, can be made use of.

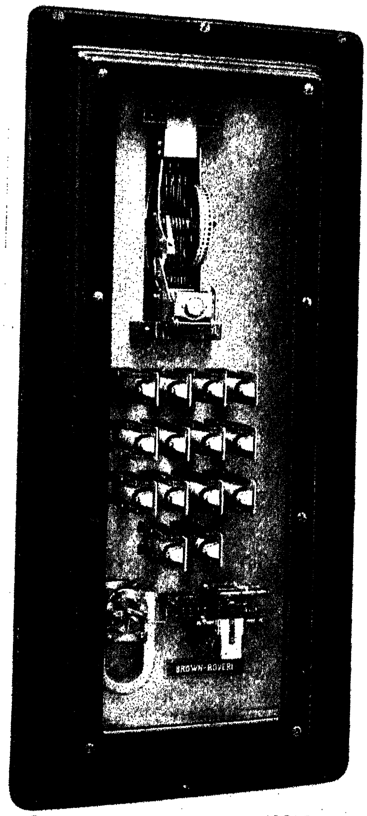


Fig. 4. — Remote control by selectors according to the single impulse process, year 1935.

The described design of the single impulse control system is characterized by the small amount of apparatus required and the clearly laid-out connections. The rotary selectors used have, usually, 51 switching positions, so that they are sufficient for the control and signalling indication of 25 organs, each with two positions. For each remote operation the following apparatus is required:— a control switch, a control double relay, a double relay at the emitter end and a position-indicating relay for each signal. Fig. 4 shows a selector equipment which consists of not only the rotary selector, but also of the relay for the reception of polarized impulses and for the automatic supervision of disturbance. A signal-reporting relay is shown in Fig. 5 and a control double relay is shown in Fig. 6. The time of rotation of the selector, i. e. the longest possible time for the execution of a control and signal operation is about five seconds, with this design.

IV. THE DESIGN ACCORDING TO THE CODED IMPULSE SYSTEM.

The coded impulse system of remote control is used for a plant either with a very big number of signals or with a pilot line liable to trouble, where direct-current transmission is eliminated because a metallic connection between the pilot line and the apparatus connected up is inadmissible. Thus,

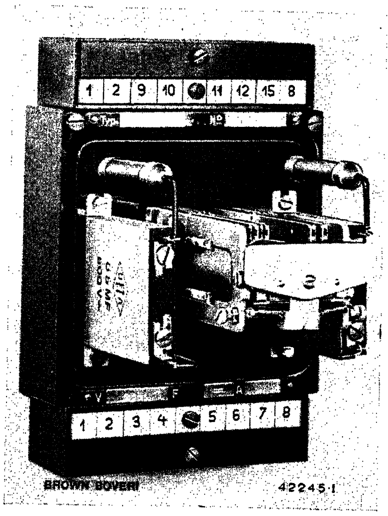


Fig. 5. — Position-indicating relay in individual housing, cover removed.

one is no longer free to choose the kind of current used for remote transmission. The Brown Boveri coded impulse control takes this fact into account, in so far as it works with direct current in exactly similar manner as with alternating current of any frequency, whereby for both senses of transmission (controlling and signalling back) a single kind of current only, for example, alternating current of a single frequency or modulated carrier wave suffices. The local circuits at the sending station and in the remotely controlled station are independent of the pilot circuit and are operated in all cases by direct current taken from a small battery or a metal rectifier. With the design according to the coded impulse process, as well, the selectors are normally at rest and are made to complete one rotation in order to transmit a control order or a signal. The selectors do not close the receiving circuit directly, but through intermediate relays, the so-called combination relays, the connections to the contacts of which form the individual receiving circuits. The advance movement of the selectors takes place, as in the single impulse system, by means of current impulses sent over the pilot line. The number of impulses is the same for every dispatch. These impulses cannot be made use of directly to actuate the signal receiving relays. In order to transmit a certain signal number, the selector is retained in a given position for a short time, which may be about 0·1 seconds. This takes place through the insertion of a pause in the impulse transmission. A time relay in the receiving post actuates the receiver-intermediate relay, which corresponds to the selector contact which the brush arm is in contact with. A holding circuit causes every receiver-intermediate relay, which is once excited, to remain attracted, till the end of a full rotation of the selector. The number of the lengthened impulse pauses is, also, the same for all signal transmissions. Thus the selector equipment can be built for one, two and three position signals. The number of receiver-intermediate relays excited during a rotation is supervised by a special counting connection. Having moved through all the positions, which are connected up to receiver-intermediate relays, the selector comes to a special test position. In this position the transmission of further impulses from the signalling station is interrupted and a checking impulse is sent from the apparatus at the receiving end. This impulse will be sent out, only, if the right number of receiver-intermediate relays is excited and the station at the sending end can receive it only if the selector is found to be in the testing position. In this way it will be automatically determined whether all the impulses arrive at the receiving end, or whether one or more current impulses are suppressed or are induced by external voltages. When the test impulse arrives and the right choice of receiver-intermediate relays is confirmed, the transmission of further switching impulses, having a fresh short-time stop of the selector, in order to distinguish the order for switching-in and switching-out of the selected organ, is effected. This concludes the process of control transmission and the selector at the receiving end is brought to an operating position, in which the contacts of the excited receiver-intermediate relay are fed, so that the selected circuit is brought into action. The operating position is followed by three further positions, out of which two are meant for the return signalling of the accomplishment of the switching-in or out and one for a cutting-out impulse. This latter impulse will always be sent from the control post, and only if the selected position-announcing relay is in the position corresponding to that particular incoming return signal. If this is not the case, the "cut-out" sign is suppressed and a new rotation of the selector takes place with a further selection and actuation of the position-announcing relays. At each starting of the selector, the duration of the impulse for the first selector step will be lengthened with the help of a time relay, and the selectors can only leave their position of rest when a prolonged impulse of this kind comes in. If a selector is not in its rest position when this occurs, it will automatically be brought into this position and in doing so it applies a voltage to the pilot lead for as long a period as is necessary for it to reach the rest position. There is, thus, an automatic guarantee that the selector starting times will always be the same, a test connection for the continuation of the synchronous movement of both selectors till the end of the process of selection, and a further supervision of the correct transmission of impulses and pauses and the actuation of the receiver relay.

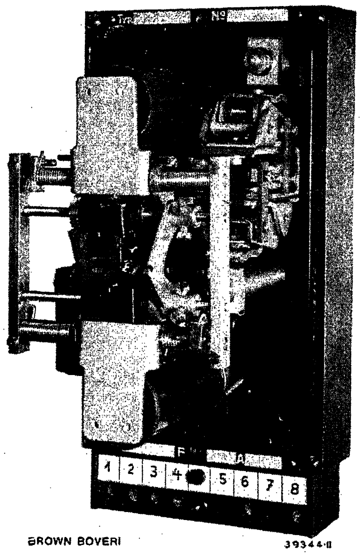


Fig. 6. — Double control-contactor with automatic anti-pumping device and closing contacts, for 250 A.

The oscillogram of the current imposed on the pilot-lead, shown in Fig. 7, illustrates the procedure

more clearly than does the above description. The oscillogram shows also the high-speed of transmission of the device, which requires only a time of about two seconds for the execution of a control operation together with the position announcement, including the time proper for actuating the switches.

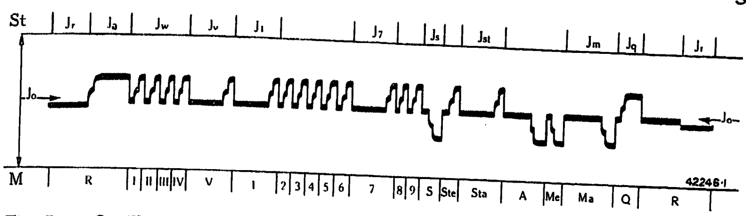


Fig. 7. — Oscillogram of the impulse groups to transmit a control and a position indicating signal.

Positions of selectors:—
1—9. Positions for choice of signals.
A. Position for carrying out impulse.
1—V. Position for preliminary selection (selection of station).
M_a. Position for signalling back "Out".
M_e. Position for signalling back "In".
Q. Position for signalling acknowledgement.
R. Position of rest.
S. Position for testing selector synchronism.
St_a. Position for control impulse "Out".
St_e. Position for control impulse "In".
Current characteristic:—
J_a. Starting-up impulse.
M. Current in signalling back sense.
J_o. Line of no current.
J_r. Rest-current for continuous supervision.
St. Current in "control" sense.
J_v. Impulse to close combination relay V (choice of substation V).
J_w. Impulse to move selector round without effect.
J_1 and J_7. Impulses to close combination relays of signal 17.
J_m. Impulse pause for back signal.
J_q. Acknowledgement signal.
J_s. Impulse for selector synchronism control.
J_{st}. Impulses pause for control order emitted.

As compared to the single impulse process in which the duration of individual impulses and pauses plays no essential part, the impulse process makes use of time-relays which maintain their time lag exactly and independently of accidental variations of the auxiliary source of current. Fig. 8 shows a relay which can be set for a contact time lag of 60—120 milli-seconds, and which can also work very exactly when voltage variations up to 30 % take place. The robust construction of this relay is especially remarkable; it guarantees a long life even though the frequency of switching be very great.

Apart from this, the apparatus which are used for the construction of the remote control system according to the coded impulse process are exactly the same as those used for the single impulse process. Of course, the selector equipments contain a larger number of relays which are necessitated by the increased number of signals and supervisory circuits. However, the control switch, the control double relay and the position signalling relays, are exactly the same. The equipment for coded impulse remote control is manufactured in three sizes, and for actuating and position signalling for 15 organs with signals of one figure, for 36 organs with signals of two figures and for 180 organs with signals of three figures. For big plants, it is advantageous to bring the position-signalling relays within common housings in order to reduce the space required. In such cases, 36 double relays are grouped in a single housing, as Fig. 9 shows.

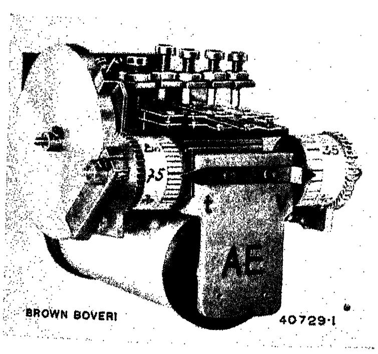


Fig. 8. — Relay with time lag independent of voltage and which can be set from 60 to 120 milliseconds.

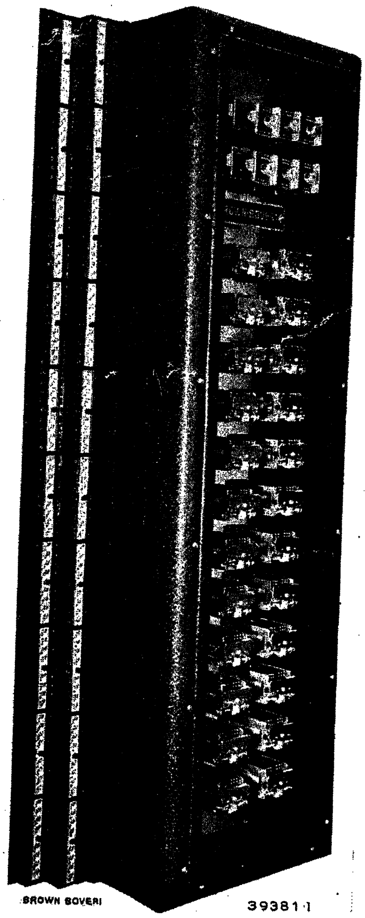


Fig. 9. — Double relays in common housing for position signalling of 36 remote-controlled breakers.

V. THE CHARACTERISTICS OF THE BROWN BOVERI APPARATUS.

As already mentioned, the principle of selector remote-controlling gears and also such as work on the coded impulse process, have become common property to-day. Both designs described here show, however, a series of special advantages, the most important among these being the automatic supervision of all signalling circuits. For switching supervision with local control, it has been taken for granted for a long time that all supervisory circuits are to be so connected

that the occurrences of trouble in the equipment should not produce the effect of a wrong state of affairs, but should show up the troubles as such. This very important stipulation is fulfilled in the design under consideration, as well. There are double relays normally energized connected to the signalling contacts to be supervised. If a circuit fails, the relay which falls, initiates a signal transmission and an indication is given in the control post, which signal circuit is affected by the failure. In similar manner, the receiver relays at the control post are supervised, and it can never happen that a signal is suppressed as a result of non-operation of the remote-control equipment or of one of the connecting leads. The rest-current supervision extends also to the pilot leads, whereby distinction is made between transient and intermittent troubles. This automatic supervision is made use of, fundamentally, in the same way in the system which works on the single impulse process as in the coded impulse remote-control system. In the latter system the indication of trouble, in the pilot-lead and the individual signal circuits, is effected by means of special trouble indicating lights. In the single impulse system this is left out and the reporting of trouble is carried out by stopping the selector in the corresponding control or signal position and by three common signal lights showing the place of failure (control post, pilot lead, or remote-controlled plant). The number of the affected circuit can be read-off from the selector.

Further, in the construction of the equipment, special care was taken in order that the remote-control devices be sufficient to meet the demands of communication engineering as well as those of heavy current engineering. The individual apparatus are, therefore, so built that the room taken up by them is not more than what one is used to, with communication equipment. Nevertheless, all the usual measures taken in heavy current plants, as for example, measures as regards variations of the auxiliary voltage, terminal marking for every individual connection, well-secured screw terminals, dust-proof housing, etc. are found here. The equipments belonging to the remote-controlled heavy-current plant, for instance the control relay, satisfy throughout the safety regulations relating thereto, and have a test voltage of 2 E + 1000 V. All the apparatus connected to the weak-current leads correspond similarly to the stipulations of communication engineering, so that the smallest energy of transmission, less than one voltampere, will suffice. The isolating of the pilot leads in the coded impulse process is carried out through isolating transformers, the test voltages of which depends upon the rated voltage of the high voltage line which goes over the high-tension poles.

VI. REMOTE METERING.

The equipment for remote metering forms the second big group of apparatus for remote supervision. Its principle is the transformation of the measured quantity into an auxiliary quantity, which cannot be altered by the changing properties of the pilot leads. One expects the remote metering to be able to transmit the instrument readings over any lines with changing resistance and insulating properties. The process which is generally carried out to-day, consists of transforming the measured values into a frequency proportional to the said values, which, nevertheless, will not be transmitted as sinusoidal alternating current but as periodic impulses emitted as D.C. or A.C. A revolving apparatus, which is built as a sort of electricity meter, works as the emitting apparatus and during every rotation it closes a contact. By these contacts the pilot lead for measurements is periodically placed under tension, whereby the frequency of impulse, i. e. the number of impulses in the unit of time, gives the measured value. Fig. 10 shows an impulse frequency emitter of this type used in power-measurement work for alternating current with unequally loaded phases. At the receiving post, the frequency on the transmitted impulse must be represented by the position of the pointer. Most devices to be found on the market, built to this principle, use receivers which transform the impulse frequency back into an electrical magnitude, so that it can be led to a normal measuring instrument. This new transformation is, however, neither necessary nor suitable, in so far as it is not a case of the sum of several remote meterings. The indicating instrument should preferably not be an intensity-measuring instrument in which its errors in measurement are added to the unavoidable inaccuracies of the emitter. Brown Boveri have developed a process by which the transformation of the impulse frequency into an indicating position is managed by pure mechanical means. The process

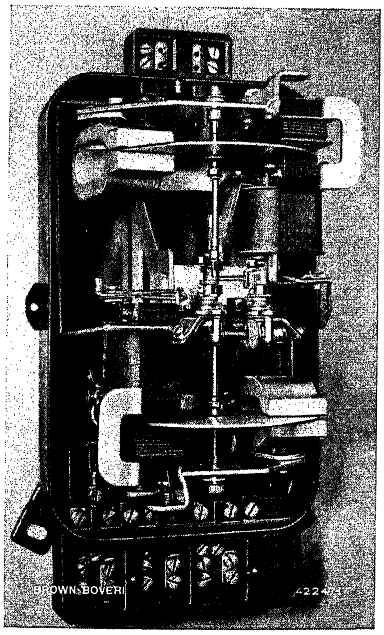


Fig. 10. — Wattmetric remote-metering emitter on the impulse frequency principle.

consists of a comparison, at the receiving post, of the measuring frequency with a second impulse frequency of constant value produced in the receiver station by a contact pendulum. The pendulum can be common to a number of remote measurements, and its accuracy is several times that of an electrical measuring instrument.

The fundamental construction of the remote metering receiver is given in Fig. 11. The incoming impulses are led to the coil of the magnet M_1. Its armature, with the help of ratchets a_1, a_2, and a_3 actuates the toothed wheels which will at least be three in number. The pointer F of the instrument rotates against the tension of a spring, with the rod which carries it. This rod S is always carried away by the wheel which makes the biggest angle of deflection. The coil of the second magnet M_2 is connected to

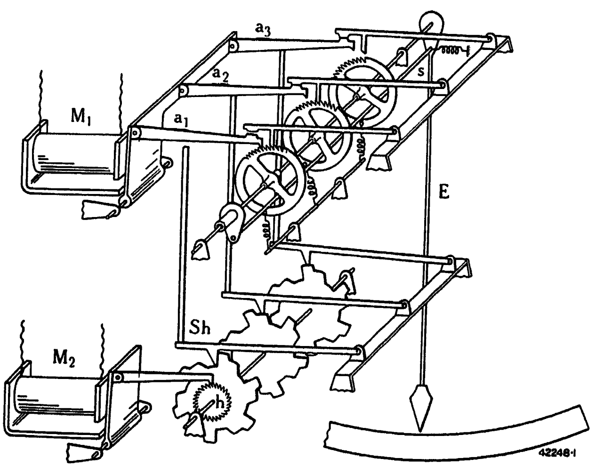


Fig. 11. — Fundamental design of a mechanical receiver for remote-metering according to the impulse frequency principle.

the electrical contact pendulum and it maintains an impulse after equal intervals of time, for instance after every second. With this, the toothed wheel h is moved further, step by step and its motion is transmitted through the cam wheels which are coupled to it. The motion of the thrust lever Sh is taken from the cam wheels. In the lowest position, there is no connection between the thrust lever and the switch ratchets, so that the latter are brought into mesh with the wheels. The armature of the magnet M_1 can, therefore, move a toothed wheel further, step by step. In the medium position of the thrust lever, it lifts the switch ratchets so high, that they come out of mesh and no further movement happens to the wheel. In the highest position of the thrust lever the switch ratchets will be raised so that the stop-pawl is disengaged, as a result of which the wheel turns back into its original position.

For the actual operation of the apparatus, eight wheels are necessary, and not three as shown in Fig. 11. The interval of time for the adjustment of the pointer with falling measured values, is shortened to a third by this. Fig. 12 shows such an indicating apparatus with an arc-shaped scale to fit in a round housing.

As compared to the electrical measurements, the mechanical indicating apparatus has a big torque at its disposal. The establishment of reliable limiting contacts presents no difficulties. For the addition of several measured values, the receiver will be coupled to rotating resistances which feed an electrical adding instrument by a parallel connection.

In many cases, for conveying several remote measurements, a single pilot circuit only will be available. If, in spite of this, all the measurement magnitudes have to be shown simultaneously in the receiving station, the same process, on which the remote control apparatus is built, can be used, namely the periodic connecting together of the emitter and receiver, which correspond to each other. As the remote metering receiver retains the last measuring value given, when the remote metering emitter and the local comparison impulse emitter are simultaneously and temporarily cut out, a selector pair is used for periodic switching over, which is controlled from the contact pendulum of the emitting station; when this is done, the further switching on movement is carried out, fundamentally, as in an impulse remote-control equipment.

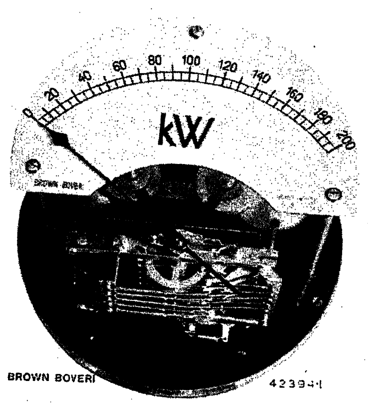


Fig. 12. — Remote-metering receiver with circle scale for lodging in a circular housing.

Remote measuring devices also call for automatic supervision of the circuits and especially of the pilot line. Rupture of a circuit would otherwise lead to the erroneous indication "zero" of the magnitude measured. The process described, when on the subject of remote-control equipments, of rest-position supervision of the pilot lines can also be applied to remote metering, so that the latter can enjoy the same quality of great service reliability, which characterizes the Brown Boveri remote control equipments.

(MS 976) *O. Plechl. (Mo.)*

THE BALANCING OF MASSES IN ROTATING BODIES.

Decimal index 621—755.

I. INTRODUCTION.

THE speeds called for by modern machine designs are constantly increasing and require perfect balancing of the rotating masses involved. This is attained by the addition of weights, which are added during the balancing tests. Efficient balancing machines are, now, available to simplify the work which was entirely entrusted to specialists, in earlier days. As, however, balancing is, often, an urgent necessity in plants — power stations or industrial plants — where the aforesaid special balancing machines are not available, it may be of interest to give a summary, here, of simple balancing methods which can be applied. This will be done without going into those theoretical principles which govern the balancing of masses and have been examined exhaustively in technical treatises, such as Stodola's work on the steam turbine, for example.

To begin with, it will be assumed that the rotor to be balanced is so supported in its bearings that it is only free to vibrate in a horizontal plane and that, when at rest, its spindle always returns to the same position.

To begin with, there are three characteristic cases of unbalance, each of which is marked by its own kind of vibration.

1. *Purely static unbalance.* — The distribution of weight in the rotor is symmetrical as regards the medium plane C-C, but the center of gravity is not located exactly on the axis of rotation (Fig. 1). Two forces A and B of equal magnitude then act on the rotor, symmetrically to the point of gravity. If, now, the rotor were free, i. e. could move without being constrained by the bearings, its axis would describe the track illustrated in Fig. 2. As, however, the rotor is only free to move in the horizontal plane, a vibration is set up, according to Fig. 3, in which the rotor axis A-A is displaced constantly parallel to itself.

2. *Purely dynamic unbalance.* — The distribution of weight in the rotor, as shown in Fig. 4, is symmetrical as regards the center of gravity which is located, in the present case, on the rotor axis. If the rotor could rotate freely, the axis would describe a movement, under the influence of forces A and B, as illustrated in Fig. 5. As, however, it can only move freely in a horizontal plane, a rotary oscillation is set up round the center of gravity, as shown in Fig. 6.

3. *Mixed unbalance.* — Case 1 and 2 alone are of very rare occurrence and, practically, all cases observed, are a combination of 1 and 2. This combined unbalance can, however, be decomposed into a purely static one and a purely dynamic one, generally located in different planes.

Before going further into the question of the said decomposition of unbalances, a few words should be said on the relation between unbalance weight and oscillation amplitude. Fig. 7 shows the position of a rotor rotating in bearings which only allow lateral displacement, Fig. 7 illustrating the moment of maximum displacement to the right. Let x be the displacement from the medium position and K the point of maximum displacement (which can be determined in the manner explained later on). Point K lags by an angle φ (referred to sense of rotation) behind the unbalanced weight A. For a given

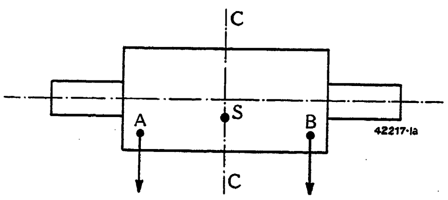


Fig. 1.

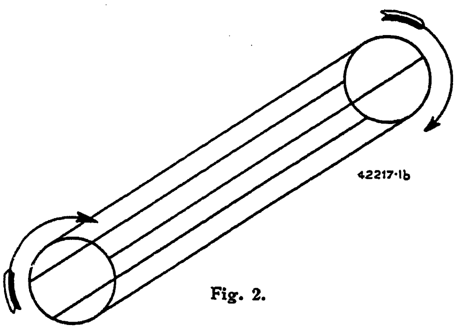


Fig. 2.

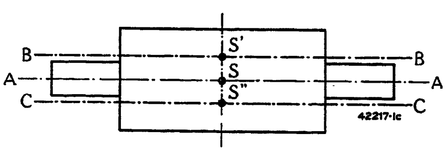


Fig. 3.

Figs. 1—3. — Purely static unbalance.

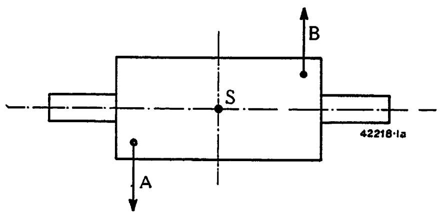


Fig. 4.

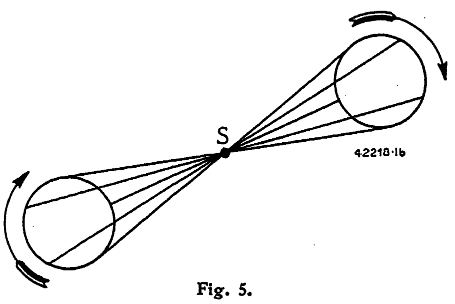


Fig. 5.

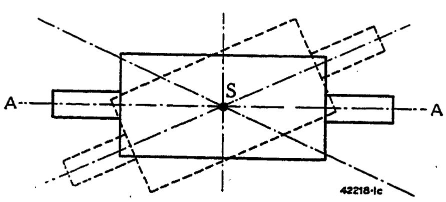


Fig. 6.

Figs. 4—6. — Purely dynamic unbalance.

balancing equipment and a given rotor this angle φ (sometimes incorrectly termed phase displacement) *is, solely, dependent on the speed of rotation, while the amplitude of oscillation is dependent on the said speed and on the magnitude of the unbalance.*

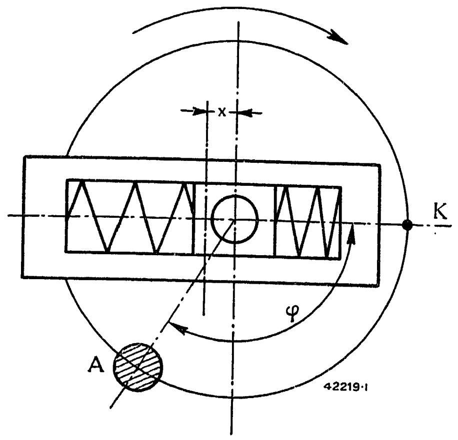
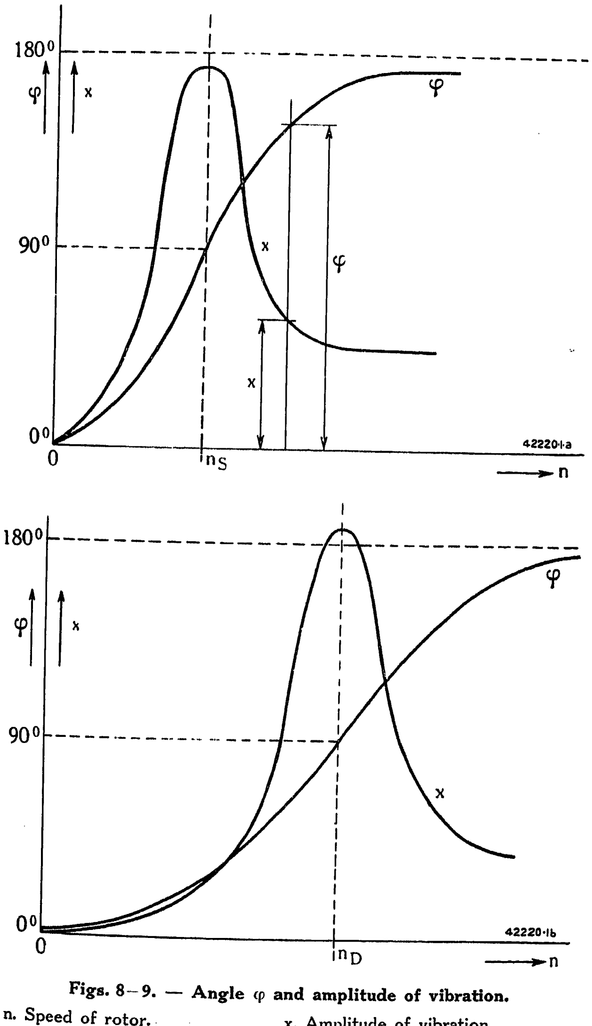


Fig. 7. — Amplitude of vibration and point of maximum displacement.



Figs. 8–9. — Angle φ and amplitude of vibration.

n. Speed of rotor.
n_S. Static resonance speed.
n_D. Dynamic resonance speed.
x. Amplitude of vibration.
φ. Angle between point of maximum displacement and the unbalance.

The curves of Fig. 8 give the value of the angle φ and the amplitude of oscillation x in function of the speed. These curves show that there is a speed at which — and in the neighbourhood of which — the amplitude of oscillation is very great. This is due to the fact that the speed of the rotor comes into resonance with the oscillations proper of the whole system composed of the rotor and its flexible bearing supports. At these so-termed resonance speeds the angle of lag $\varphi = 90^0$ and, at much higher speeds, this angle reaches nearly 180^0. The curves of Fig. 8 are independent of the sense of rotation.

In cases of purely dynamic unbalance, conditions are similar. Here, also, angle φ and amplitude of vibration x are given under the form of curves (Fig. 9). The only difference is that the sense of maximum displacement x, on either side of the center of gravity, are opposed to each other and grow in direct ratio to the distance ℓ from the said center of gravity (Fig. 10). The resonance has the same character as in purely static unbalance and appears again at $\varphi = 90^0$.

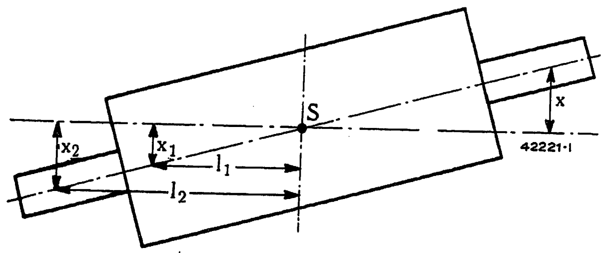


Fig. 10. — Amplitude of vibration in the case of purely dynamic unbalance.

As Figs. 8 and 9 show, the static and dynamic resonance speeds do not generally coincide. Their relative position depends on the shape of the rotating body, as is easily proved by the equations which govern $\pm$ oscillations. For the usual shapes of turbine and generator rotors, the dynamic resonance speed is about twice as high as the static one.

II. PRACTICAL BALANCING.

The rotor to be tested is cradled in the manner illustrated in Fig. 11. It has, thus, the necessary freedom to move in a horizontal plane. As, now, a

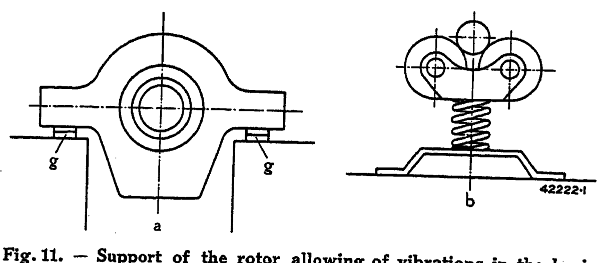


Fig. 11. — Support of the rotor allowing of vibrations in the horizontal plane.

g. Rubber pad support.

rigid rotor, which is well balanced at a given speed, remains steady at all speeds, the balancing equipment can be so designed that a low resonance speed is created. For big rotors, resonance speeds of between 200, 250 r. p. m. are chosen and, for small rotors, up to 600 r. p. m. The resonance speed is determined by the thickness of the rubber pad in devices such as that shown in Fig. 11a and by the dimensions of the spiral spring in devices such as that of Fig. 11b. The drive is best carried out through a belt from a separate motor.

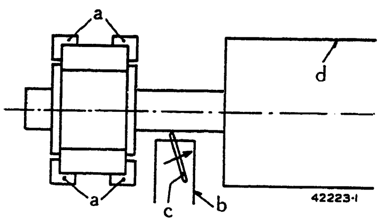


Fig. 12. — **Equipment for making the pencil marks.**

a. Rubber pad supports.
b. Rigid independent support put up.
c. Coloured pencil.
d. Rotor.

In order to determine which point has the greatest displacement, a firmly supported coloured pencil is brought up close to the shaft journal of the revolving rotor (Fig. 12), until it touches the journal lightly; the shorter the coloured streak produced, the worse the balance and the easier the task of balancing. In judging the indications thus produced, a beginning must be made from the middle of the streak (Fig. 13).

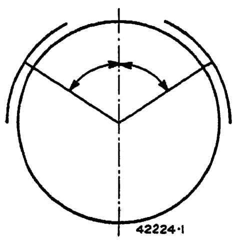


Fig. 13. — Determination of results of markings.

In order that a free vibration be produced, the driving belt is slackened before the marks are made. When passing through the speed desired (when the speed is dropping), marks are made at both shaft ends, when possible. When several marks are made, the same speed must be adhered to, exactly. A primary condition for good balancing results is, obviously, that the journals should be straight and run true.

In order to shorten the coming paragraphs, it should be said here that by the addition of static-correction weights is meant putting weights on the rotor according to Fig. 14a and by the addition of dynamic-correction weights is meant putting weights on the rotor according to Fig. 14b. At the beginning of the operation, the rotor is allowed to rotate first in order to ascertain at what speeds the static and dynamic resonances appear.

III. STATIC AND DYNAMIC BALANCING WITH BOTH SENSES OF ROTATION.

Marks are made on the rotor for both senses of rotation of the latter, in one sense with a red

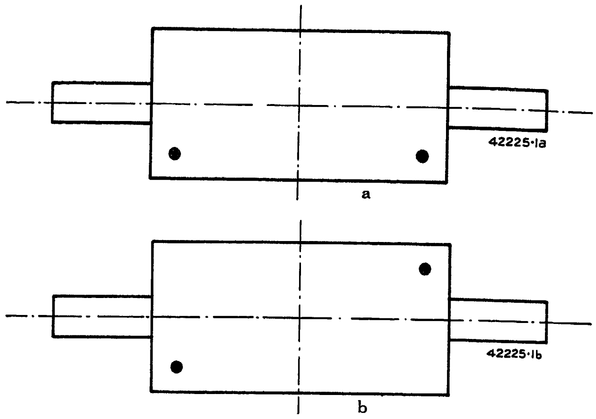


Fig. 14. — Addition of correction balance weights to the rotor.
a. Static. b. Dynamic.

pencil, for example, and in the other with a blue one. For this the r. p. m. must be about 10 % above the static resonance speed. Further, care must be taken that the marking speeds, in forward and reverse rotation, are as equal as possible. The symmetry line L-L between the marks determine the plane of unbalance (Fig. 15). *To speak generally, the marks always lag behind the point of unbalance or "heavy spot". The correction weight to be added must be placed behind the mark.*

The magnitude of the correction weight must be ascertained by tests made with repeated runnings of the rotor. If the pencil marks are always recorded on the same side of the shaft, and if the vibrations at the resonance speed seem less accentuated than before, the correction weights put on are still too small. If, however, the marks appear on the other side of the shaft, the correction weights added are too big. In this way tests are continued until running at the speed corresponding to static resonance is, practically, smooth.

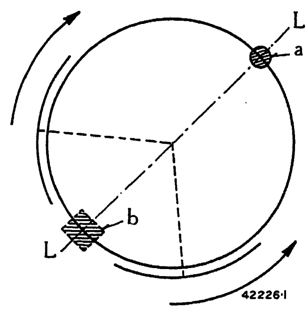


Fig. 15. — Determination of the plane of unbalance.

a. Unbalance (unknown).
b. Correction balance weight to be added.

It is now possible to begin investigation of the dynamic unbalance; for this it is advantageous to choose a speed which is also about 10 % above the resonance r. p. m. There, again, pencil marks are made for both senses of rotation. The marks should now appear on the two opposite sides of the shaft journals.

If the said marks are not opposite each other, this is a proof that there is still some static unbalance. The correction weights for dynamic unbalance

are added according to the same principle as used for static balancing.

By repetition of this process and by appropriate modification of the correction weights, smooth running at the dynamic resonance speed is, finally, attained. Finally, the static markings are repeated, again, so as to make whatever adjustments may still be necessary. If this has to be done, the dynamic balancing must again be tested.

IV. STATIC AND DYNAMIC BALANCING WITH ONE SENSE OF ROTATION.

As opposed to the two methods just described, the speed with which tests are begun, in the present case, is at least 30% above the dynamic resonance r. p. m. Then, according to how the pencil markings show, either static or dynamic balancing is begun with. The markings, only one on each shaft journal, have to be made with great care, so that they are of short length. It is recommendable to repeat the first marks two or three times before determining

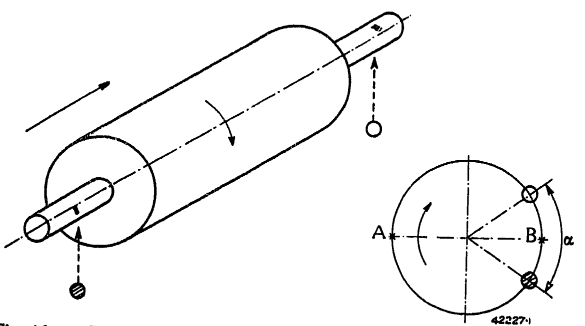


Fig. 16. — Static and dynamic balancing with one sense of rotation $\alpha < 90°$.

their exact location. In Fig. 16 the mark O designates the middle of the marks on one journal and ● that on the other journal.

According to the position of the first marks, several different cases can be differentiated.

1. The marks are so made that angle α (Fig. 16) is *smaller than 90°*. In this case, angle α is divided into two equal parts and the line of separation gives, approximately, the position of the plane of *static unbalance*. The balance fault is located at A and the counter weight should be added at B. This static balancing is carried further until the vibrations have practically disappeared when the rotor passes through the *static* resonance r. p. m. The modified weight should always be placed on the *same spot B*. The better the static balance the further the marks travel from one another until they are, finally, opposite one another. Dynamic balancing is, now, carried out in the plane determined by the two last marks located opposite each other. This is done by locating the correction weights on the said marks, or, still better, about 10° behind them. Balancing is now continued weights being always placed on the same spot until running has become considerably smoother when passing through the dynamic resonance r. p. m. In this dynamic balancing method the marks tend to move towards each other again and end by coming on the same side. The plane thus determined which is again statically unbalanced does not, generally, coincide with the one in which static balancing was carried out earlier (B in Fig. 16). Static balancing must, again, be carried out in this new plane until the marks are again opposite each other. Then an improvement of the remanent dynamic unbalance is effected and the process goes on in an alternation of static and dynamic balancing operations until the rotor runs satisfactorily, at all speeds.

2. If the middle of the marks are so located that α is bigger than 90° (Fig. 17), dynamic balancing is begun with and this in plane L which makes the same angle with the radii through the middle of the marks (Fig. 17). Correction weights are placed at A and B. Balancing is continued in this plane until smooth running is attained when the rotor passes through the dynamic resonance speed. As this dynamic balancing progresses, the two marks have moved towards each other, and finally appear on the same side and give, approximately, the plane of the static unbalance still to be dealt with. Balancing is pursued, as explained under 1, until the rotor runs smoothly at all speeds.

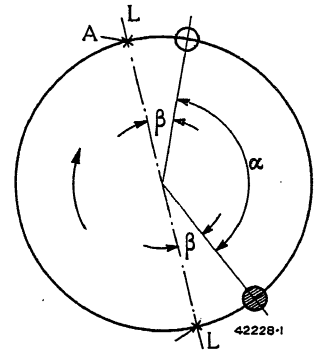


Fig. 17. — Balancing with one sense of rotation $\alpha > 90°$.

3. A special case is presented when one marking runs all round the journal, while the other one is very short and distinct. The rotor vibrates strongly at one journal and practically, not at all at the other. In this case, static and dynamic unbalance are nearly in the same plane. A start is made with static balancing in the plane of the short marks, and this is carried on until running becomes smooth when passing through the static resonance speed. In the meantime the marks round the journal disappear and are replaced by a mark which gets more and more definite. If smooth running at static resonance speed is attained, the marks indicate the plane of dynamic unbalance which plane does not deviate much from the one of static unbalance. Dynamic balancing is now pursued in the newly determined plane, as explained under 1 and 2.

V. RELATION OF THE STATIC TO THE DYNAMIC RESONANCE SPEED.

The equation of the vibrations proper of the system in the case of the static resonance speed (the rotor shaft oscillating parallel to itself, according to Fig. 3) are as follows:

$$M \frac{d^2x}{dt^2} = -2\,k\,x$$

where

M = mass of rotor

x = amplitude of vibration and kx the spring force acting on each of the two bearings.

The number of the vibrations is given by this differential equation, being

$$n_{stat} = \frac{1}{2\pi}\sqrt{\frac{2\,k}{M}}$$

It is, thus, dependent on the spring strength of the support and the mass of the rotor.

In the case of the dynamic resonance speed, for the same rotor

$$\Theta \frac{d^2\varphi}{dt^2} = -2\,k\,\ell^2\varphi$$

Θ is the moment of inertia of the mass referred to medium point S of the vibration; k is the spring

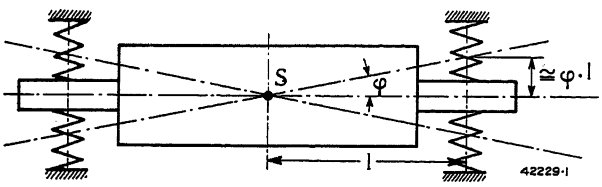


Fig. 18. — Conditions in the case of dynamic resonance speed.

constant, as before, of the support, while angle of rotation φ and dimension ℓ can be seen in Fig. 18.

The number of vibrations is given, here, by

$$n_{dyn} = \frac{1}{2\pi}\sqrt{\frac{2\,k\,\ell^2}{\Theta}}$$

This means that the dynamic resonance speed of the rotor is dependent, apart from k, on the distance between bearings and the moment of inertia of the mass, i. e. for a given mass it depends on the shape.

The relation of the static to the dynamic resonance speed is thus determined by

$$\frac{n_{stat}}{n_{dyn}} = \frac{1}{\ell}\sqrt{\frac{\Theta}{M}}$$

VI. ULTERIOR BALANCING AT FULL SPEED.

This method is applied to advantage on machines on which it is easy to secure correction balancing weights. The B case is difficult to handle and a removal of the rotor and its placing on an emergency balancing machine is the most expedient solution.

A. *Static unbalance* (discs, etc., rotors, in which only one journal vibrates strongly). The method assumes that the amplitudes of vibration, caused by an unbalance on a bearing, for example, are proportional to the unbalanced force in the rotor. This assumption is, certainly, correct for all amplitudes which can be allowed without danger for a machine running at high or full speed.

1. The amplitude of vibration is first measured before any alteration is attempted, this being done with a vibrometer or vibrograph secured to a bearing pedestal.

Alternatively, a dial micrometer can be mounted on a support independent of the set being balanced, and, resting against the bearing or shaft, gives a measure of the vibration amplitude.

2. A weight of known magnitude[1] is secured to any point a′ (Fig. 19) and the machine brought to the speed chosen for balancing, which, if possible, should be its full-rated speed, the vibrations which then occur are measured. For example, the amplitude of vibration corresponds to 1·5 divisions of the instrument used.

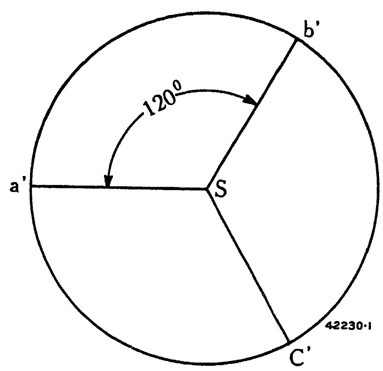


Fig. 19. — Addition of a weight of determined magnitude at a′; then at b′ and, finally at c′.

3. The same weight is displaced on the same circumference by 120° (Fig. 19) and secured in position b′; the vibrations which arise are measured at exactly the same speed and sense of rotation and with *unchanged instruments*. The amplitude is, now, 3·5 divisions, for example.

4. The weight is, finally, secured at c′, the amplitude being, for instance, 2·5 divisions, here.

From these four tests, which must be carried out at the same speed, the necessary data can be deducted to allow of ascertaining the magnitude and sense of the unbalance.

[1] The magnitude of the weight chosen must, of course, be in a certain ratio to the weight of the piece being balanced, if an effective influence on the vibrations is to be attained.

The surplus weight U present in the system forms resultants R_a, R_b, and R_c with the weight mounted at a′, b′, and c′, which resultants are proportional to the amplitudes measured, according to what was assumed. The parallelogram of forces (Fig. 20) shows, at once, that the end point 0 of the unbalance U looked for is located at the center of a circle having a radius of G dimension, and also that the end points a, b, and c of the resultants R_a, R_b, and R_c are also located on this circumference. Fig. 20, thus, allows of reaching the following conclusion:— If it is possible to determine a point S on a circumference with center at 0 and a radius of the magnitude of G, the connecting straight lines of which to points a, b, and c at 120° from one another are in the same ratio as $R_a : R_b : R_c = 1{\cdot}5 : 3{\cdot}5 : 2{\cdot}5$, then S0 is the unbalance sought for, both in magnitude and direction.

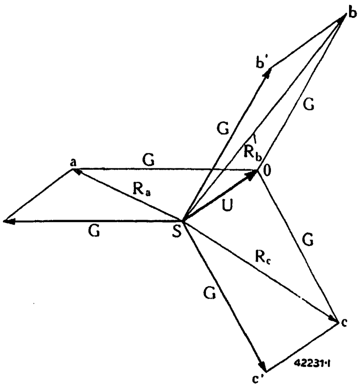


Fig. 20. — Parallelogram of forces.

5. *Constructive determination of the unbalance* (Fig. 21).—The task is, therefore, to determine point S (Fig. 20), so that the connecting straight lines from S to a, b, c are in the same ratio to each other as $R_a : R_b : R_c$, which for the example under consideration is $1{\cdot}5 : 3{\cdot}5 : 2{\cdot}5$. To this end, the weight G placed successively at a′, b′, and c′ (Fig. 19) is drawn in to a given scale both in magnitude and sense from a point 0 (Fig. 21).

First a straight line is laid through points a and b and perpendiculars drawn in at a and b. At a, the amplitude measured when the known weight was at a′, is marked off on the said perpendiculars (on both sides) to a given scale (1 division of the instrument = 1 cm for example). This amplitude was 1·5 divisions in the assumption made, or 1·5 cm to the scale. In b, the amplitude measured for weight in position b′ is marked of on the perpendiculars to a—b (but only on one side). This is 3·5 divisions or 3·5 cm. By connecting up points x, y, and z thus obtained, points A and B are determined on a—b. A circle is now drawn through A and B, having as center 0_1. As is known, this circle is the locus of all points the connecting lines of which are in the same ratio to a and b as $1{\cdot}5 : 3{\cdot}5$.

The circle is, therefore, also the locus of the points of intersection of the resultants R_a and R_b which are in the ratio $1{\cdot}5 : 3{\cdot}5$ according to the measurements carried out.

In similar manner the locus of all points is, now, determined over b—c, the connecting lines of which are in the same ratios to b and c as $R_b : R_c = 3{\cdot}5 : 2{\cdot}5$ (perpendiculars at point b and c to the line b—c, 3·5 cm being measured off in b and 2·5 cm in c, respectively, which leads to the determination of points of intersection C and D and to a circle round 0_2).

The third circle round 0_3 over c—a is only a verification of the correction of the diagram, and is also established in similar manner. The three circles intersect at points S and S_1. As, now, the lines of connection from point S to points a, b, and c and those from S_1 to a, b, and c are in the ratios $1{\cdot}5 : 3{\cdot}5 : 2{\cdot}5 = R_a : R_b : R_c$, two solutions for the magnitude and sense of the unbalance are attained in S0 and $S_1$0.

By taking account of the scale of force chosen, the weight of U can be read off straight, and, thus, the magnitude and sense of the correction balance weight is determined.

It is possible to determine which solution is the correct one by comparing the amplitude of vibration

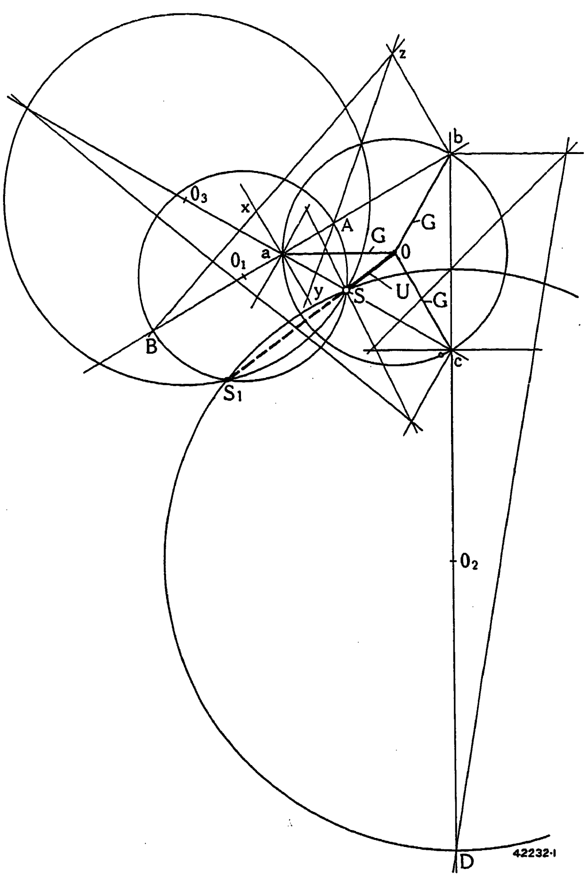


Fig. 21. — Geometrical determination of sense and magnitude of the unbalance.

determined before balancing began (see under A_1) with one of the three amplitudes of R_a, R_b, or R_c. As the amplitudes are proportional to the forces, a decision can be reached as to which solution is the correct one.

B. *Static and dynamic unbalance* (rotors of turbo-generators and of steam turbines).

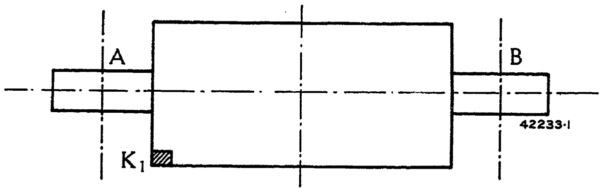


Fig. 22.

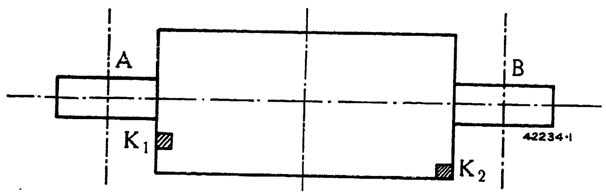


Fig. 23.

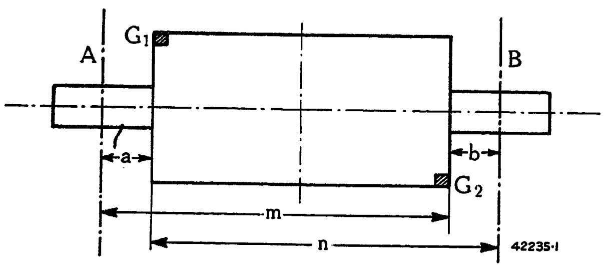


Fig. 24.

Figs. 22—24. — Placing and distribution on the ends of the rotor of the weights which have been determined according in Fig. 21.

1. Determination of the weight K_1, on one end of the rotor (Fig. 22) which compensates all forces and torques which act on the middle of the bearing as a result of a state of unbalance. This is effected by the method under A, by putting on a predetermined weight, three times (each point at 120^0 from the former one). The weight K_1, which is finally determined by geometrical construction according to Fig. 21, is then *secured* definitely in position.

2. K_2 at the other rotor end is determined once K_1 (Fig. 23) is in position. Thus, the whole effect of the unbalance on the middle of the bearing B is compensated. For the moment, however, K_2 is not put on. If K_2 were put on, after being determined according to Fig. 21, the rotor would run smoothly at B, but vibrations would be set up again at A, owing to the reaction of K_2 on A. The necessity, therefore, arises to decompose weight K_2 into weights G_1 and G_2 (Fig. 24) in such a manner that:—

(a) The influence of G_1 and G_2 on bearing point B is the same as K_2 alone.

(b) The weights G_1 and G_2 do not create new forces, i. e. the sum of the torques generated by G_1 and G_2 as referred to B is equal to zero.

Put under the form of an equation condition a is

$$K_2 \cdot m = G_2 \cdot m - G_1 \cdot a$$

and condition b is

$$G_1 \cdot n - G_2 \cdot b = 0$$

G_1 and G_2 can be determined from these two equations and can be secured on the rotor, being lodged in the plane passing through the axis and through K_2.

(MS 967) *F. Ribary. (Mo.)*

NOTES.

Quick-acting regulation of paper-making machine drives.

Decimal index 621.34:676.2.05.

ONE of the essential conditions of every paper-making machine drive is the absolute maintenance of the working speed set to. Every arbitrary modification of the said speed means a variation in the thickness and, therefore, of the weight per square metre of the paper manufactured. If the fluctuations in weight exceed a certain value, set by the paper trade, the manufactured product may be refused by the buyer. In any case, the excess weight is not paid for so that more material is being delivered without a corresponding increase in price.

In order to maintain the working speed of the paper-making machine constant, in spite of load fluctuations and of variations in voltage or frequency on the supply system, Brown Boveri make use of a quick-acting regulation the principal elements of which are a very sensitive quick-acting regulator, a tachometer dynamo and the requisite switching gear. The regulator proper is built to the design of the well-known Brown Boveri quick-acting regulator, thousands of which are working to-day; this apparatus is characterized by high precision combined with an efficient damping and recall, so that occasional speed fluctuations are suppressed at the moment of their initiation and this without any hunting. As opposed to the vibratory regulators working on the oscillation principle, the Brown Boveri regulator is subject to no wear and calls for no special supervision so that a very high degree of reliability in service is assured.

The regulator is influenced by the tachometer dynamo, which is either direct-coupled to the driving motor of the paper-making machine or is driven by belt or chain. Every

fluctuation in speed is expressed by a variation in the voltage of the dynamo, which, in turn, causes the quick-acting regulator to act and to bring back the driving motor to the required speed, by a corresponding variation in the voltage of the control set (Ward-Leonard set or booster set).

Fig. 1 shows the switchgear cubicle for a paper-making machine drive of 110 kW rated load, controlled in Ward-Leonard connection; this is a plant delivered to Brazil. The two switchboard panels on the left are for the synchronous motor of the control set which is started up and stopped by push-buttons, by means of contactors and a starting transformer. This arrangement is the simplest method of service imaginable. The synchronous motor plays a big part in improving the power factor of the mill system.

The working speed which happens to be required is set with very fine graduation from the operating side by means of a small apparatus which takes up very little room; to this end, the operator has about 500 setting steps at his disposal. The requisite instruments for service supervision such as current and voltage meters and a speed-indicating instrument are combined with the said apparatus.

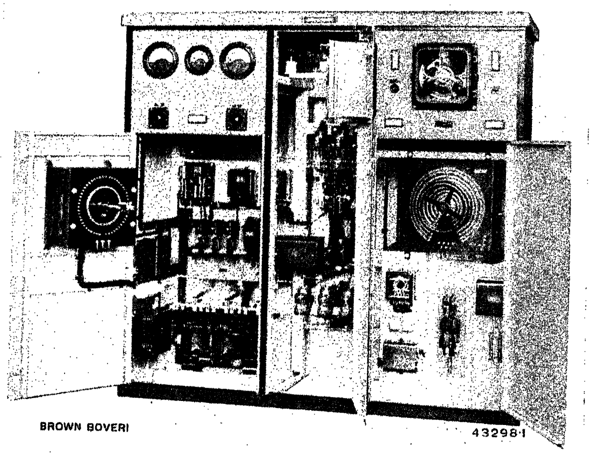


Fig. 1. — Switchgear cubicle for a paper-making machine drive. On the left, two panels for the automatic starting of the synchronous motor of the control set; on the right, the panel for the quick-acting regulating equipment.

The field rheostat for the Ward-Leonard dynamo, seen in the illustration, is equipped for remote electrical control and has 180 steps, each of which is again subdivided by the quick-acting regulator into a great number of fine intermediate steps. The field rheostat is controlled by the quick-acting regulator, when it reaches its end-travel positions.

Recently, the three-phase shunt commutator motor has been introduced successfully to paper-making machine drives. In cases where a wide range of speed regulation is called for, quick-acting regulation is very recommendable. Fig. 2 shows a drive of this kind. The tachometer dynamo works on a relay built to the quick acting-regulator principle; the latter controls the small motor for brush displacement through a reversing contactor. The relay in question is equipped with a dynamic recall device which, combined with certain appropriate measures, prevents over-regulation, and therefore hunting.

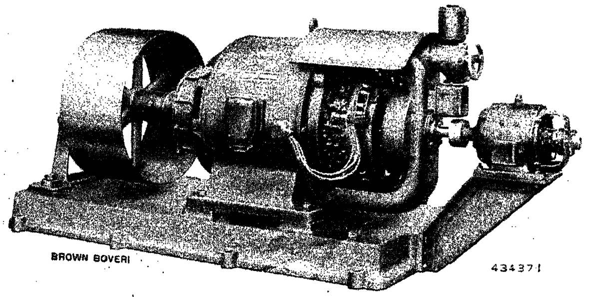


Fig. 2. — Three-phase shunt commutator motor with flanged on gear drive and tachometer dynamo coupled up, for the automatic quick-acting regulation of the speed set to, intended for the drive of a paper-making machine.

For the drives of big high-speed paper-making machines which are all of the electrical sectional type, to-day, it is of great importance that the working speed set to should be maintained with the greatest accuracy. This condition is often the essential factor for attaining working speeds exceeding 300 m/per min. The quick-acting regulation provided to meet these conditions comprises a variant of the standard Brown Boveri quick-acting regulator: — the frequency regulator. The latter assures that the master or pilot frequency remains constant within the very narrow range of $\pm 0{\cdot}15$ to $0{\cdot}25\%$ and, as the said master frequency is an absolute measure of the working speed, the latter is maintained with great precision, as well.

The switchgear cubicle usually employed for regulating gear of this type is shown in Fig. 3. It is mounted on the operating side of the paper-making machine and contains — apart from the voltmeter and ammeter — an indicating and a recording instrument for the working speed. The latter is set absolutely smoothly (without steps)

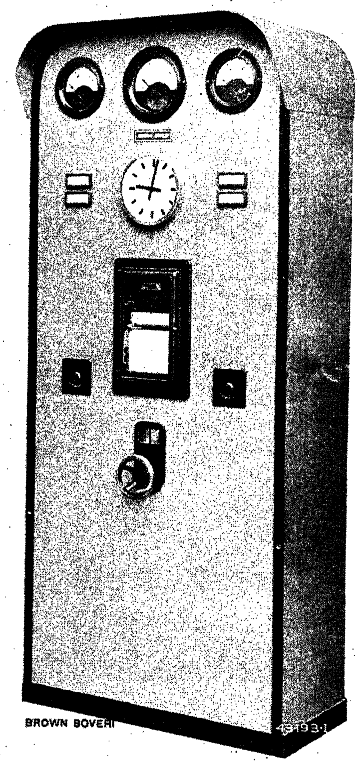


Fig. 3. — Switchgear cubicle for the control of the sectional drive of a paper-making machine, with automatic quick-acting regulation.

by means of the handwheel shown acting through a three-phase movable choke coil.

Brown Boveri has delivered a very large number of quick-acting regulating equipments for paper-making machines, which have given every satisfaction; many of these have been for drives manufactured by other makers. Quick-acting regulation has proved a valuable improvement for drives on account of the severer requirements now made as regards homogeneity of the paper manufactured and as regards rational operation. Every paper-making machine drive to-day should have its quick-acting regulating equipment.

(MS 980) *R. Schnitzer. (Mo.)*

Some new aerial ropeways equipped with Brown Boveri electric drives.

Decimal index 625. 433.

AERIAL ropeways are one of the oldest methods of transport in mountainous regions. The first ones, which were of the simplest design, were used, practically exclusively, for goods traffic. To-day, the number of passengers who may be carried on aerial ropeways, which are operating under concession of a local authority, is limited,

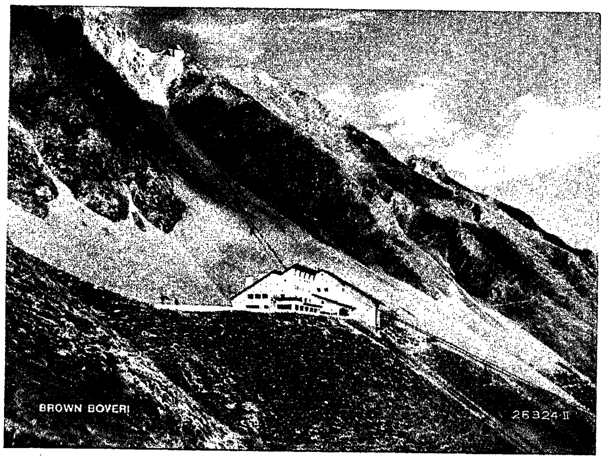


Fig. 1. — Intermediate station on the Nordketten Railway near Innsbruck.

in Switzerland, to four and they are used, chiefly, for local convenience and for carrying winter-sport passengers. A line of this type was built by Robert Aebi Co., in Zurich, to link up Beckenried on the lake of Lucerne and the Klewenalp; it was 3111 m long with a difference of altitude of 1143 m. The travelling speed was 4 m/s and the driving motor a 37-kW three-phase Brown Boveri unit. This ropeway began service with great success in 1933 but the unexpectedly sharp rise in traffic, due to winter-sport passengers, soon proved that the line was quite inadequate to deal with the demand so that, as early as two years after it was built, the decision was taken to make over the ropeway so that the cars could carry 20 passengers each, while so transforming the plant that it met the Swiss Government Traffic Regulations. More details on this new aerial ropeway, for which the electrical equipment was again ordered from Brown Boveri, will be given in a coming number of the Review.

A similar plant was built by the Eisen- und Stahlwerke Oehler & Co., in Aarau, in 1935; this is the Stöckalp-Melchsee-Frutt ropeway, in Central Switzerland. This line carries four passengers per car and serves both the hotel at the higher end and the economic requirements of this alpine region. The ropeway is 3500 m long with a difference of altitude of 826 m; the travelling speed is 4 m/s. The driving plant in the lower station comprises a three-phase induction motor 40 kW, 380 V, 50 cycles, which is regulated by a change-over controller with nine starting positions.

A specially interesting plant is the one built by the firm of Bleichert in Leipzig, for public service, namely the two-section Nordkettenbahn near Innsbruck. The total length of the line is 3632 m, the lower station being at 863 m altitude and the upper one at 2258 m altitude. The drive of both sections of the line is in the intermediate station, at 1906 m altitude. The journey on the lower section takes 12 to 14 minutes at a speed of 3·6—4·0 m/s and 5 minutes on the upper section at 3 m/s. Two cars run in shuttle service on the lower section, each taking 24 passengers while there is only one car on the upper and much shorter line. The electric drives of the two line sections are independent of one another and each has a D. C. main motor of 60 kW continuous rating, in Ward-Leonard connection, with a buffer battery. The power supply, from the Innsbruck Electricity Works, is at 5000 V, 50 cycles which is stepped down in two transformers, each of 125 kVA continuous rating, to 380 V, for

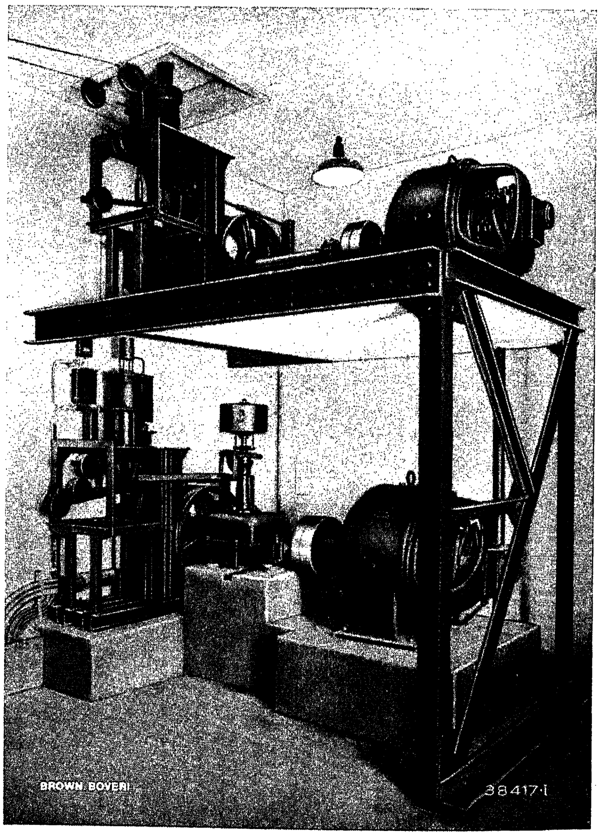


Fig. 2. — Main and auxiliary drives on the Wank Railway.

connecting to the two control sets. These control sets consist of a three-phase induction motor of 70 kW, a D. C. generator of 85 kW and an exciter of 7 kW for the regulation of the generator voltage by means of a change-over controller with 18 switching steps and for the constant independent excitation of the winding motor. There is a buffer machine of 55 kW coupled to the set the duty of which is to get over the load peaks which occur on lines of this nature; this machine gives back superfluous power to a storage battery, it operates automatically as a motor and as a generator according to the service requirements. This solution which was chosen for reasons of power economy allows of having a store of power in reserve if, by any chance, the three-phase current supply should fail. Further, there is a stand-by petrol-electric set of 100 H. P. available to supply D. C. current, the duty of which is to support the buffer battery in its duty of operating the line at ordinary speed, when the three-phase supply is cut out for long periods. Over and above these measures, the line is equipped with the usual safety devices including auxiliary drive for each line section. A whole series of switching possibilities allow of keeping up service under all conditions. The electric equipment was supplied by the Austrian Brown, Boveri Co., in Vienna.

The Obervellach aerial ropeway (Austria) built by the Pohlig firm on the brake-rope system is a passenger and goods railway. On a length of 1000 m it has a difference of altitude of 360 m and is built for a travelling speed of 4 m/s. Drive is by two D. C. motors each of 45-kW rated load; these are controlled on the Ward-Leonard system, independently of each other.

Another plant, built by the Bleichert firm, Leipzig, with electrical equipment by the Brown, Boveri & Co., Mannheim, is the Wank Railway near Partenkirchen which is 2670 m long. Drive is by a 66-kW D. C. motor in Ward-Leonard connection. There are seven alternatives in case of emergency, namely:— ordinary service with current connection of main drive to the supply system through the control set, power supply by two Diesel-electric stand-by sets for full traffic-capacity conditions or else supply by one of the said sets for a lower travelling speed. The first and the second-last working conditions can also be used with the auxiliary drive. Under ordinary conditions, the power supply is A. C. single-phase, 2000 V, 60 cycles.

Apart from the plants just mentioned which are equipped in Ward-Leonard connection, according to the regulations in force in the countries in which they are situated, mention should be made of the Sestrières and Banchetta lines built by the firm of Bleichert in Leipzig. The first of these is in two sections, each 902 m long, the total difference in altitude being 562 m, while the second is in one section 2730 m long with a difference of altitude of 517 m. The electric equipment was delivered by Tecnomasio Italiano Brown Boveri, Milan, and consists of two three-phase motors of 80 kW and 41 kW for the main drive of the first plant and of 92 kW for the second plant, at 220 V supply voltage, 50 cycles. The travelling speed is 4 and 2 m/s for the Sestrières line and 5 m/s for the Banchetta line. A detailed description of similar plants and of the safety devices generally used in aerial ropeways will be found in the Brown Boveri Review of the year 1926 and 1928 in which the Italian Merano-Avelengo and Oropa-Mucronesee plants are described.

The Wetterhorn lift near Grindelwald, which started operations in the year 1908, should be of historical interest. This lift equipped by the von Roll Iron Works in Berne, and having electrical equipment by Brown Boveri, was used for tourist traffic only. It had a carrying capacity of 16 passengers per cage and the distance travelled over was 530 m with a difference of altitude of 405 m; the

Fig. 3. — Wetterhorn lift.

speed of the lift was 1·5 m/s the grade being 61 to 206 %. Drive was by a D. C. shunt motor, of 52 kW at 750 r. p. m. and 800 V terminal voltage, connected to a single-phase 2500 V supply at 46 cycles through a cascade converter. This, the first Swiss aerial ropeway, which was dismantled a short time ago, as it was running at a loss, furnished valuable constructive data and experience in service which came in very useful for more recent plants.

To summarize, it should be said of the 50 important passenger-carrying aerial ropeways, in public service in Europe, more than a quarter are electrically equipped by Brown Boveri. This equipment is always of a type best suited to the characteristics of the line served and meets every requirement as regards safety in service, overloading capacity and little maintenance, all conditions which are demanded of the equipments of lines of this type.

(MS 959) *E. Hugentobler. (Mo.)*

Small power stations in South America.

Decimal index 621. 311. 2 (8).

THE following is a short description of some small power stations which Brown Boveri delivered to South American countries in the course of last year and which have been started up, recently.

1. *Diesel-electric power station Junta de Beneficiencia de Tumaco Narino district, Columbia.* A power station equipped with two Diesel-electric sets, having three-phase A. C. generators, each built for 100 kVA, 500 V, 60 cycles, 450 r. p. m., was put up in Tumaco, one of the Columbian harbour towns on an island on the west coast of South America. A wall-type of switchboard with three panels contains the 500-V switching and measuring equipment for the two generators as well as the apparatus on the low-voltage side of a 200-kVA transformer for stepping up the generator voltage to 2400 V.

As the plant is in close proximity to the sea shore, all iron parts are subjected to the deleterious effect of salt sea air. For this reason, all iron parts of the plant had to be galvanized and the apparatus made as air-tight as possible.

Further, four substations were put up and a high and low voltage system laid out which covers the whole island.

2. *Hydro-electric plant belonging to Mr. Fernando Perez Pallares, Ipiales, Columbia.* This plant is in the southern part of Columbia, situated in a high valley of the Andes mountains, at 3000 m altitude above sea level. It takes the place of another older plant, and is created by prolonging the existing penstock downwards, which

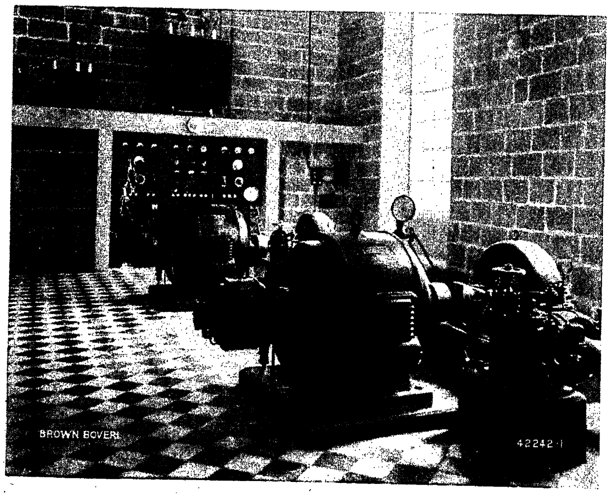


Fig. 1. — The small power station Las Lajas (South Columbia) with wall-type switchboard and transformers.

gives a head of water double the original one. There are two generating sets in the station with Pelton-wheel turbines direct-coupled to generators 144 kVA, 500 V, 60 cycles, 900 r. p. m. Fig. 1 shows the two sets and, in the background, the wall-type of switchboard as well as the power and station transformers.

The total load of the plant is led to a substation, for which Brown Boveri also supplied the electric material. The power generated supplies light and power to a textile mill and to the town of Ipiales.

3. *Diesel-electric power station of the industrial enterprises "Cima" in Manta, Ecuador.* This station supplies current to different industrial plants and also lights the town of Manta and its harbour. This is a Diesel-electric plant which, for the time being, has only a single set producing 135 kVA, three-phase A. C. current, 380 V, 60 cycles, 360 r. p. m. the voltage being stepped up in a transformer to 2400 V. Later on, it is intended to double the output by putting in a second generating set.

4. *Hydro-electric plant in Huigra, Ecuador.* This is a high-head hydro-electric station with a three-phase generator 60 kVA, 380/220 V, 60 cycles, 1200 r. p. m. direct-coupled to a Pelton-wheel turbine. Later, it is intended to put in a second generating set. This plant supplies the locality of Huigra with light and power. The electric equipment for three substations was also delivered by Brown Boveri.

5. *Thermal-electric power station Cervecería Ciudad Bolivar, Venezuela.* This beer brewery, a subsidiary of the Companía Anónima Cervecería de Caracas, gave Brown Boveri the order for the electrification of the whole brewery plant including a power station which comprises the two following sets:—

1 three-phase A. C. generator, 114 kVA, 230 V, 60 cycles, 1200 r. p. m. driven by a gas engine of 140 H.P. through a Brown Boveri spur-wheel gear with roller bearings and dip lubrication.

1 three-phase A. C. generator, 24 kVA, 230 V, 60 cycles, 1200 r. p. m. belt-driven from a steam engine.

The second set is, chiefly, a stand-by. The switching and measuring apparatus for both generators and for the distribution is lodged in a three-panel switchboard. The material delivered includes 12 driving motors with corresponding battery of switchboxes and a centrifugal pump.

6. *Diesel-electric plant for the Companía Aurifera Nazca, Peru.* This electric plant comprises four generating sets, with each one three-phase A. C. generator, 122 kVA, 230 V, 60 cycles, 300 r. p. m.; it was started up quite recently. Power distribution is at low voltage, here. The current is used to supply power and light to a gold mine. The switching and measuring equipment and the different outgoing leads are lodged in an eight-panel switchboard.

(MS 986) *W. Kissling. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2): 621. 314. 21.

READERS will be interested to hear that, apart from certain rotary machines already mentioned under the above heading, there are transformers operating to-day which have been in service for remarkably long periods without requiring any repairs whatever.

The Electricity Works of the Canton of Thurgau, situated in Arbon, have a whole series of Brown Boveri transformers on their system which have been in continuous operation for more than thirty years. Up to date, not the slightest repair has been called for on these units. These are transformers of 20 to 80 kVA ratings, 8000/350/200 V and 8000/250/144 V, 50 cycles, with workshop numbers between 6434 and 8431, that is to say, belonging to a series of products built in early days.

(MS 979) *Prop.*

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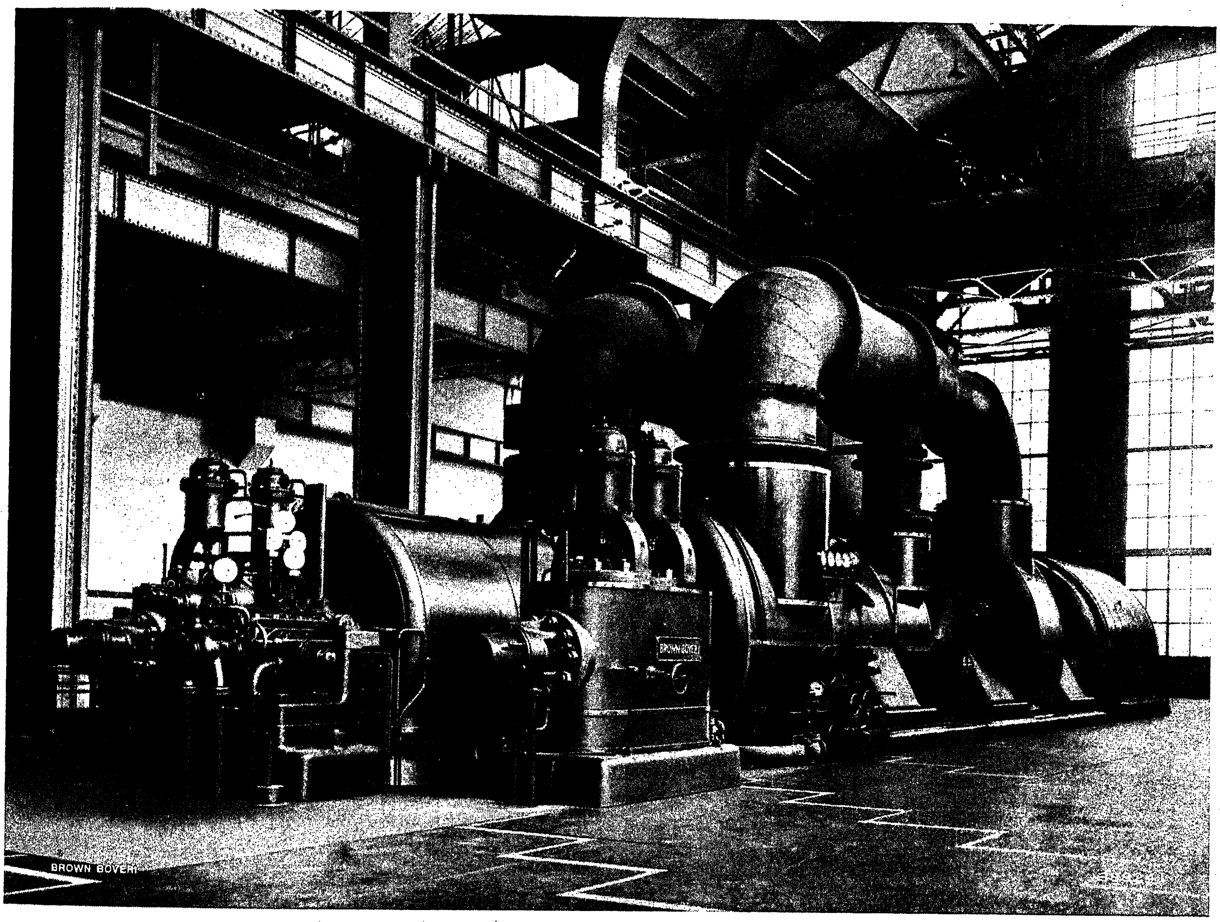

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CONTENTS:—

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The directly-heated

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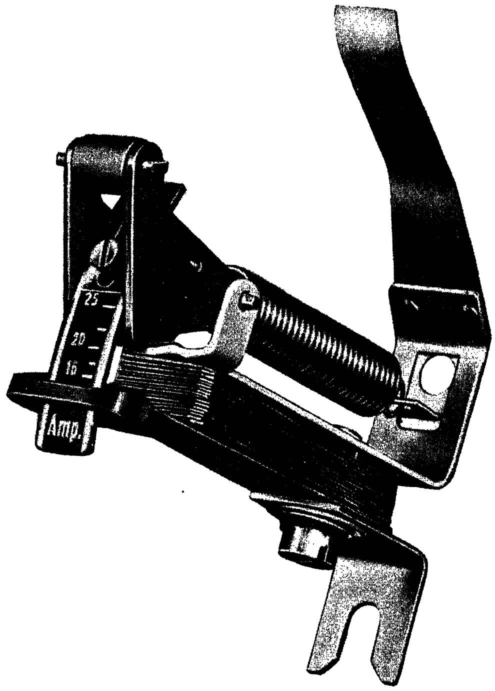
with spring-operated mechanism



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Built into motor-protection switchboxes for manual or remote control forms a complete protection for motors and lines:—

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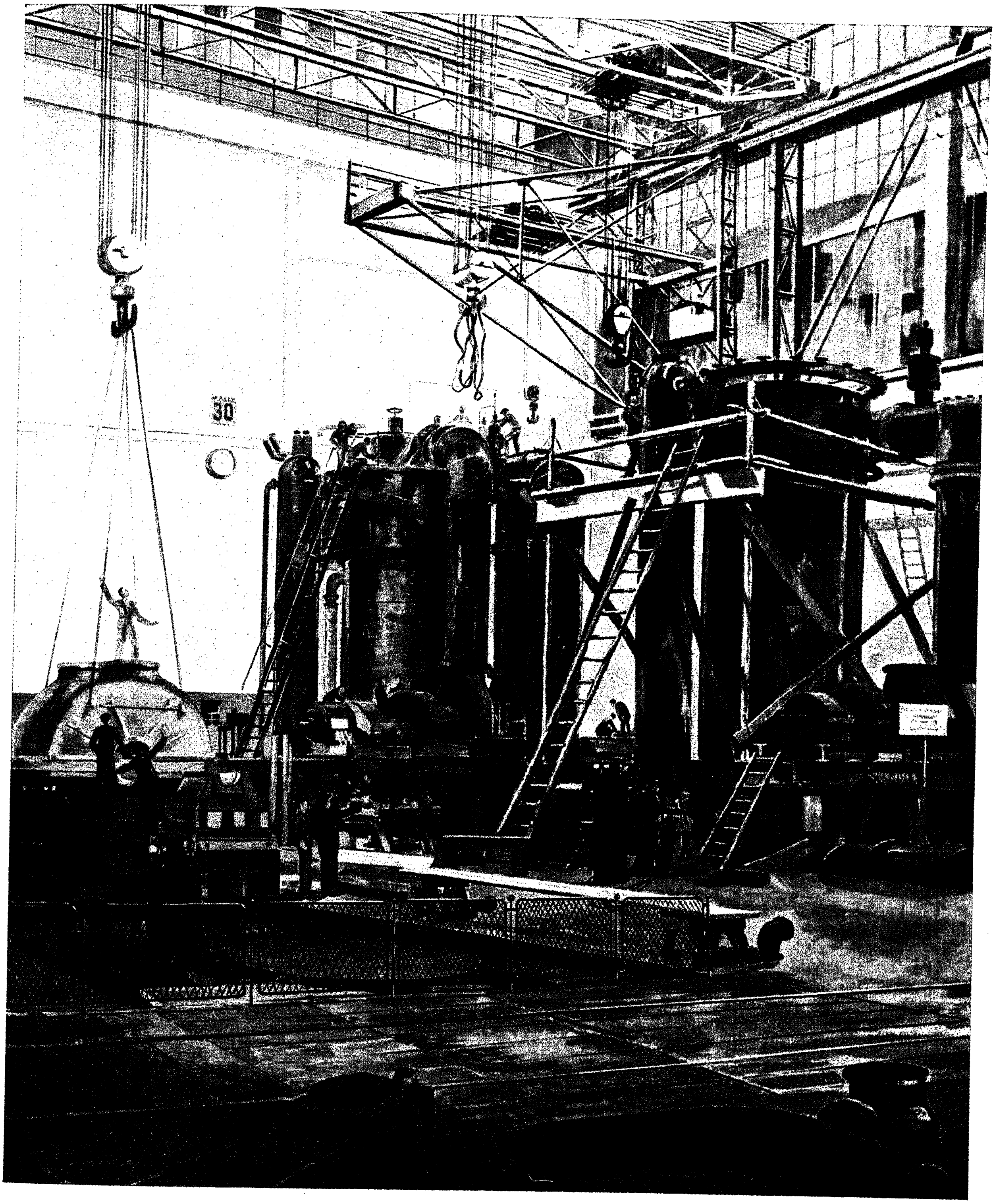
because of its great mechanical strength

because it is very short-circuit proof



BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)
TWO 75 T/H VELOX STEAM GENERATORS FOR OSLO MUNICIPAL ELECTRICITY SUPPLY (NORWAY)

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIII AUGUST, 1936 No. 8

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AUTOMATIC CHARGING AND DISCHARGING OF STORAGE BATTERIES.

Decimal index 621.356.078.

ACCUMULATORS for electric-power storage are finding constantly-increasing use, to-day, in a variety of plants, as stand-by sources of power, as auxiliaries in generating stations, substations, signalling, telephone and wireless stations as well as in laboratories; and as main source of power in electric vehicles, trucks and shunting locomotives. According to the requirements of the plant, lead, iron-nickel or cadmium-nickel cells are made use of. By using apparatus which allows of automatic and proper charging and discharging of the batteries, the life of the latter is prolonged, their service reliability enhanced and upkeep charges lowered. A suitable and reliable charging and discharging limiter is the most important item in a modern storage-battery plant.

Ampere-hour meters are often chosen to limit charging and discharging; these instruments measure the amount of current fed to, or discharged from, the battery in question. However, they are often inadequate, because that stable relationship between current absorbed and current discharged, which would be essential if ampere-hour meters are to be used is, practically, non-existent, here. Unequal charging and discharging, variations in temperature, vibrations, all go to modify the stable relationship in question and prevent the meter intervening and operating properly. It is least suitable in the case of lead cells, as these are very sensitive to improper charging limits and to over-charging.

Apart from ampere-hour meters, time- or voltage-relays are made use of for limiting charging. With these relays, as well, it is practically impossible to make an exact adjustment corresponding to the energy stored up in the battery and the different ways in which charging and discharging take place. Further, apparatus is also used in which a voltage relay is combined to a time relay in such a way that the voltage relay acts before the end charging voltage is attained and the time relay limits the time required for the complementary charge needed to finish the charging process.

Apart from the fact that this apparatus is only designed to limit the charge alone, the method of estimating the charge of a battery solely from the voltage is inexact, when the charging current is modified in order to accelerate or slow-down charging, causing the charging voltage to vary according to the curves of Fig. 1, and, further, when there are long leads between the battery and the switchgear which cause considerable voltage drops. This also applies to the limiting of charging. Thus, these apparatus cannot be used for completely automatic plants.

Brown Boveri uses the completely-automatic *Brown Boveri charge and discharge limiter* composed of a *current-compounded maximum and minimum voltage relay*, which limits the charge and discharge of a battery or initiates its limitation, as soon as the desired charged or discharged condition is reached. As the contacts of this relay are only able to handle very small amounts of power, an intermediate relay is introduced to do the switching of the main apparatus. This intermediate relay can be so set that, after a number of ordinary charges, a periodic super-charge of the battery takes place, which is requisite for its upkeep. The methods of operation of the charge and discharge limiter (represented, chiefly, by the current-compounded maximum and minimum voltage relay 6 in Fig. 8, which corresponds to completely automatic service) is explained here with the help of the voltage-current curves of a cadmium-nickel battery designated by Ca in Fig. 1. Curve sheet Fig. 1 (Ca) gives the voltage-current curves of a cadmium-nickel cell at 0 %, 20 %, 50 %, 80 % and 100 % charge and at 0 %, 20 %, 50 %, 80 %, 100 % discharge. If, now, it is desired to limit charging to a 90 % charge and discharging to 80 % discharge, the attraction curve L and the release curve E of current-compounded max. and min. voltage relay 6 must coincide with the corresponding current-voltage curves of Fig. 1 (Ca). The current dependency of this relay also allows of taking into account the influence of the voltage drop in the connecting line between battery and switchgear panel. The Brown Boveri charge and discharge limiter is thus very exact and reliable and is very suitable for supervising both semi- and fully-automatic apparatus.

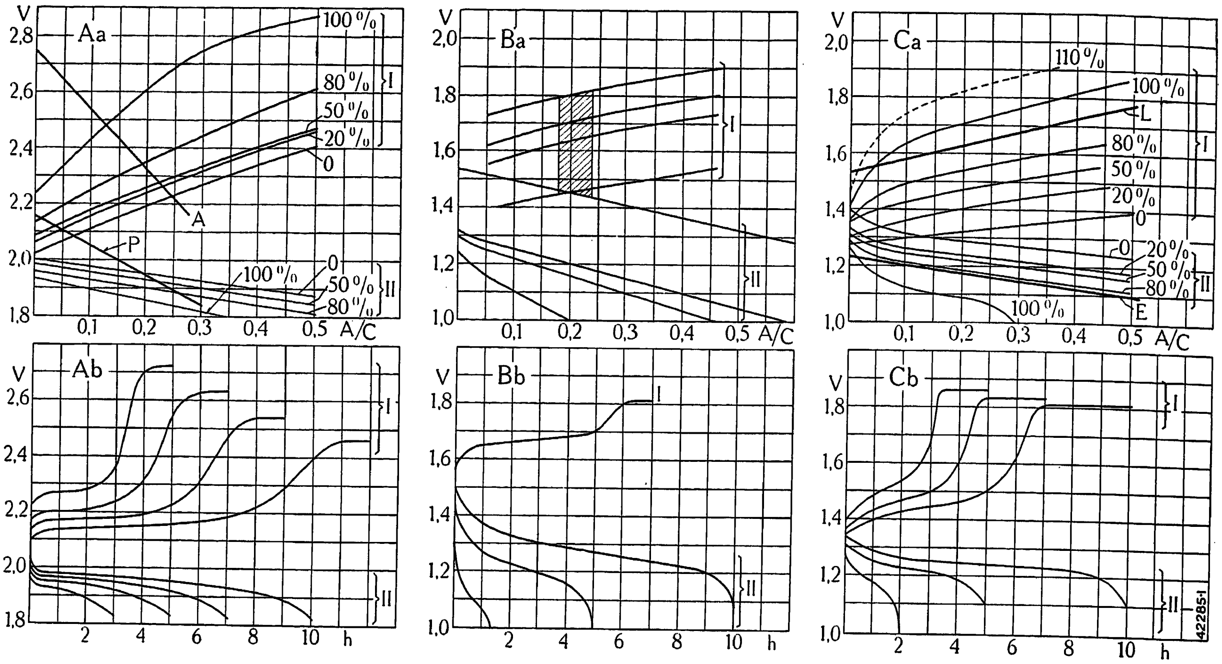


Fig. 1. — Charging and discharging characteristics of accumulator cells.

Charging and discharging voltage of a cell belonging to a lead storage battery in functions of:
Aa. The current in % of rated capacity (A/C). Ab. The time.

Charging and discharging voltages of a cell belonging to an iron-nickel storage battery, in function of:
Ba. The current in % of rated capacity (A/C). Bb. The time.

Charging and discharging voltages of a cell of a cadmium-nickel storage battery, in function of:
Ca. The current in % of the rated capacity (A/C). Cb. The time.

A. Voltage-current characteristic of the generator at charging.
P. Voltage-current characteristic of the generator when in parallel with the battery.
L. Pick-up curve of the charge and discharge limiter.
E. Fall-back curve of the charge and discharge limiter.

Table summarizing different types of charging and discharging equipments.

A. FOR NON-STATIONARY BATTERIES (semi-automatic service)

Connection	I: One charging point (Fig. 2)	II: Several charging points (Fig. 3)	III: Several charging points (Fig. 4)	IV: Several charging points (Fig. 5)
Type of charging .	One battery at a time	Several batteries in parallel	Several batteries in parallel	Several batteries in series
Voltage and current regulation by . .	Counter-compounding the generator	A series resistance for each charging point	A current limiting regulator per charging point	A common current regulator
Field of utilization .	Traction batteries (stationary batteries)	Traction batteries	Traction batteries	Signal, laboratory, automobile or stationary batteries

B. STATIONARY BATTERIES (semi- or completely-automatic service)

Connection	I: One charging point (Fig. 3)	V: Two charging points (Fig. 6)	VI: One charging point (Fig. 7)	VII: One charging point (Fig. 8)
Type of charging .	One battery at a time	Alternatively charging and discharging of two batteries	Alternatively a) Parallel service of generator and battery b) Battery charging	Alternatively discharging and charging of a battery at constant line voltage
Voltage and current regulation by . .	Counter compounding of generator	Counter compounding of generator	Charging regulator	Boosting generator and voltage regulator
Field of utilization .	Emergency and auxiliary batteries	Telephone and signal batteries	Telephone, signal, auxiliary and lighting batteries	Auxiliary, emergency and buffer batteries

1. CHARGING SETS AND PROTECTIVE DEVICES.

Brown Boveri generally uses charging converter sets composed of an induction motor with squirrel-cage rotor or centrifugal starter and a D. C. generator specially designed for the characteristics of the plant in which it will be placed. In a motor-generator set, fluctuations of the primary-supply voltage do not cause any appreciable fluctuations in the charging current, such as would occur were charging mutators used. The motors of these sets can remain connected to the supply even if the supply voltage fails. Thus, the dynamo alone must be cut out when current begins to flow back to it from the battery and must be connected up again when voltage comes back to the supply system. These two switching operations are carried out by the *reverse-current voltage relay 5*, directly, when the current is low, and by switches, controlled by the said relay, when the currents are heavy. Thermal relays and fuses are used to protect the machines and batteries against harmful overloads and too heavy currents.

2. CHARGING AND DISCHARGING DEVISES.

A distinction is made, chiefly, between charging and discharging devices, according to the Table given on page 200, which are summarily described in the following paragraphs.

A. *Non-stationary batteries.*

I. *Semi-automatic charging equipments with one charging point, according to Fig. 2.*

An equipment of this type is used to charge small and up to average-size batteries. The motor 1 is connected to the supply system by the closing of motor-contactor 8 through the insertion of plug 12. Switchbox 3 has thermal relays. The generator 2 is counter-compounded, so that the voltage rise necessary for charging is obtained, practically, without incurring losses. The sliding resistance 4 allows of adjusting the charging current to the desired value, so that charging can be carried out in a shorter or longer time, as desired. The charge limiter is composed of the current-compounded voltage relay 6 and the intermediate relay 7; this is the same apparatus as the charge and discharge limiter already described, for the completely automatic equipment, Fig. 8, it is however only used here to limit the charge. The battery is connected to the switchboard by a *plugging device* 12. Brown Boveri has a special plugging device with auxiliary contact for use here. After the motor contactor 8 has been closed, the reverse-current voltage relay 5 closes the charging circuit directly or indirectly through a contactor or similar apparatus after the set has attained rated speed. When charging is over, the intermediate relay 7 opens the circuit of the electro-magnets of contactor 3,

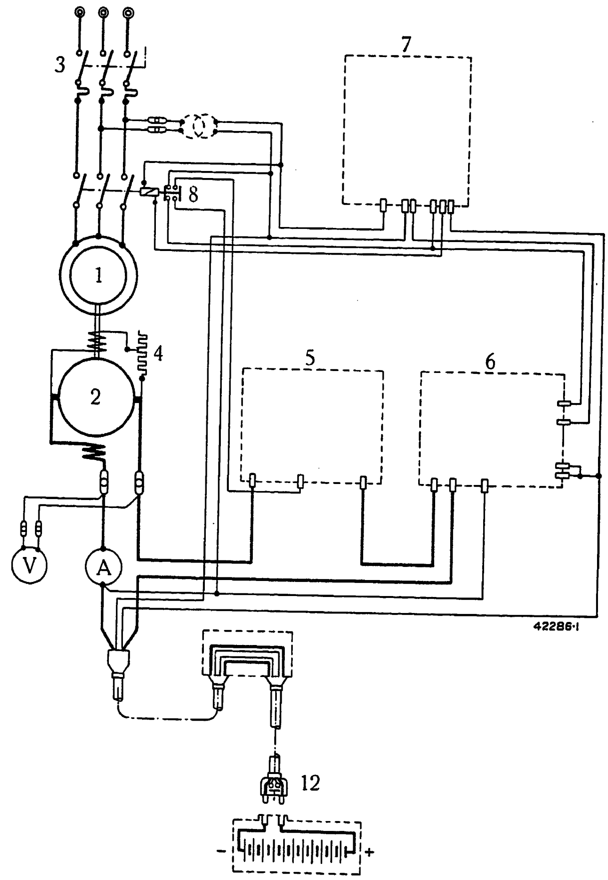


Fig. 2. — Charging equipments for non-stationary batteries (for semi-automatic service).

I. One charging point, with counter-compounded generator.
See common legends on page 204.

which causes the motor-current circuit to open. The reverse-current voltage relay 5 then separates the generator 2 from the battery.

With some small modifications, this equipment can be used for charging stationary batteries.

II. and III. *Semi-automatic charging equipments with several charging points, according to the diagrams of Figs. 3 and 4.*

These equipments allow of the *simultaneous charging of several batteries connected in parallel.* In order to allow of charging batteries located at different points and apart from the switchgear, the different connecting points have to be equipped with the Brown Boveri plugging device 12 with auxiliary contact and the corresponding switching points on the switchboard each with an automatic charge limiter 6 and 7.

In the layout shown in Fig. 3, each battery is to be connected to the common bus-bars through a series resistance 10. These resistances permit of the simultaneous charging of batteries in different states of charge, as they limit to a given value the current taken by a battery according to its charged state.

As charging progresses, the charging current falls as a result of the increase in battery counter-voltage. At the same time, the charging voltage grows as the voltage drop across the resistance 10 falls. The voltage of the generator must be set at a somewhat higher value than the highest charging voltage required by the battery and this voltage must remain constant when the number of connected batteries changes, as well as under continuously changing counter-voltage of the batteries.

Fig. 4 shows a similar arrangement; here *Brown Boveri quick-acting current-limiting regulators 13* take the place of the series resistances 10. These current-limiting regulators allow of *automatic regulation of the charge voltages without loss.* Of the batteries connected in parallel, the one which is most discharged absorbs the biggest current. Its current-limiting regulator 13 regulates the generator voltage so that the battery is protected from absorbing an excessively heavy current. The batteries which are less discharged take a current, which remains below the maximum value admissible.

The equipment shown in Fig. 3 is started up by the insertion of one of the plugs 12 in the corresponding battery plug-hole, which causes motor contactor 8 to close and connects the motor to the supply system. The charging set

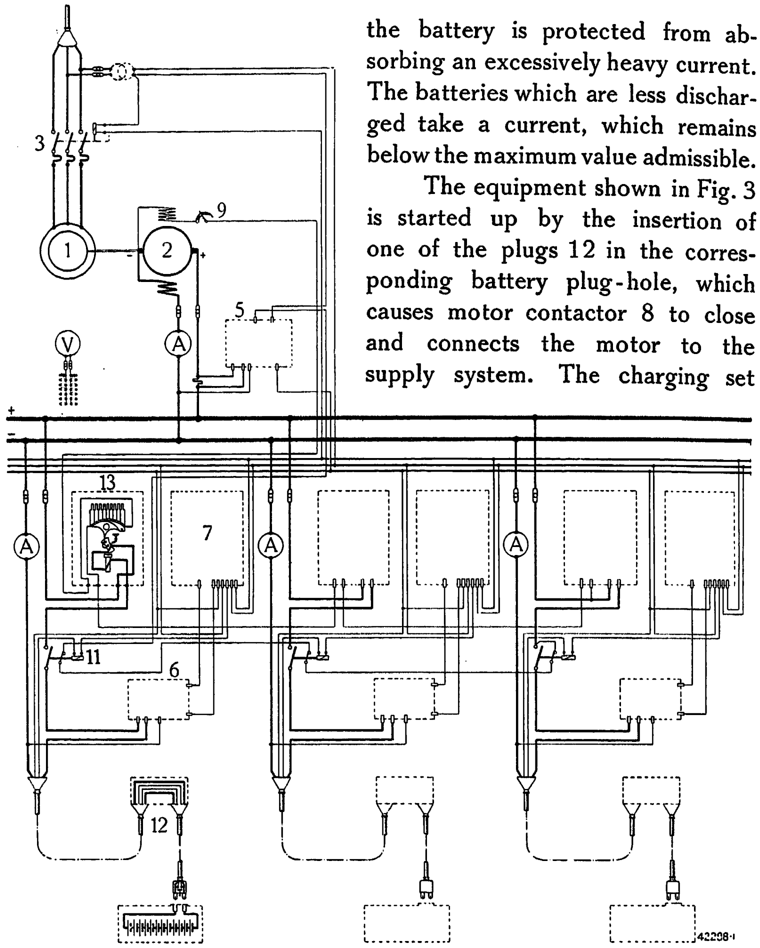


Fig. 4. — Charging equipment for non-stationary batteries (for semi-automatic service).
III. Several charging points, parallel charging with a current-limiting regulator for each charging point.

then starts and reaches its rated speed. The starting up of the equipment according to Fig. 4 differs from that of Fig. 3 in that switch 3 is closed by hand in the place of the remote-controlled contactor. In both cases the reverse-current voltage relay 5 closes contactor 11 of the corresponding charging point on the switchboard after the voltage of the generator has attained that of the battery. The charge of the battery now begins. The additional switching in of other batteries is carried out by the insertion of the corresponding plugs at the charging points and the simultaneous automatic closing of the corresponding contactors on the switchboard. When a battery is completely charged, it is immediately cut out by its charge limiter composed of relays 6 and 7 (Fig. 3), this by the opening of contactor 11. When the charge limiter of the last battery has

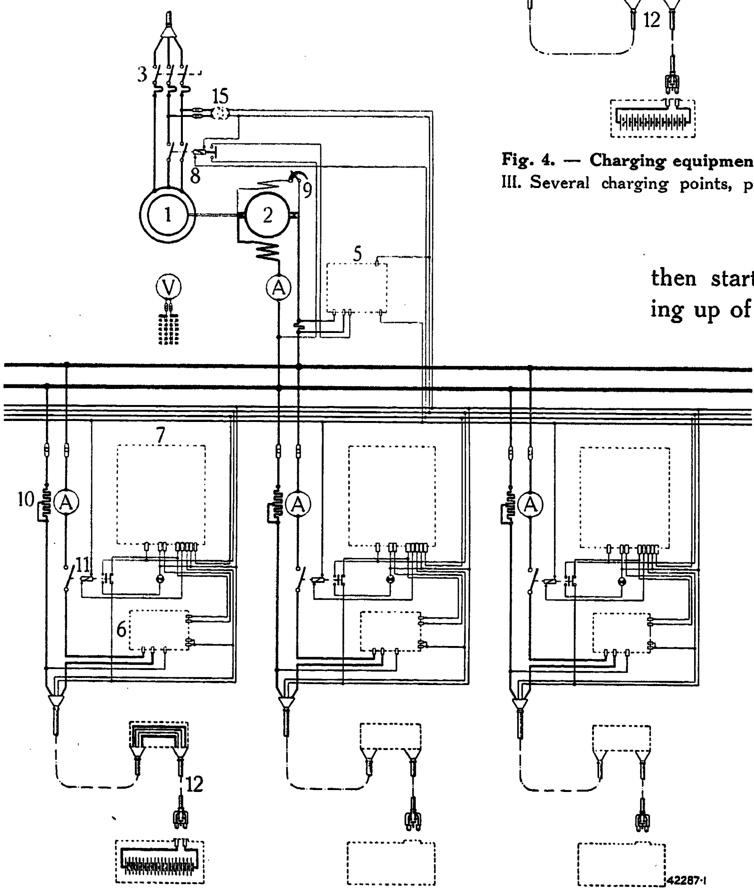


Fig. 3. — Charging equipment for non-stationary batteries (for semi-automatic service).
II. Several charging points, parallel charging with a series resistance for each charging point.

acted, the charging set is simultaneously stopped through the opening of contactor 8 or of switch 3.

The equipment according to Fig. 4 is more economical in service than that of Fig. 3 because the regulation of the charging voltage is practically without losses. On the other hand the cost of the equipment with series resistances, for small and medium-sized batteries, is generally lower than that with current-limiting regulators. This changes, however, in favour of the current-limiting regulators when big batteries are in question, because, here, the series resistances become big and relatively expensive, while causing correspondingly heavy losses.

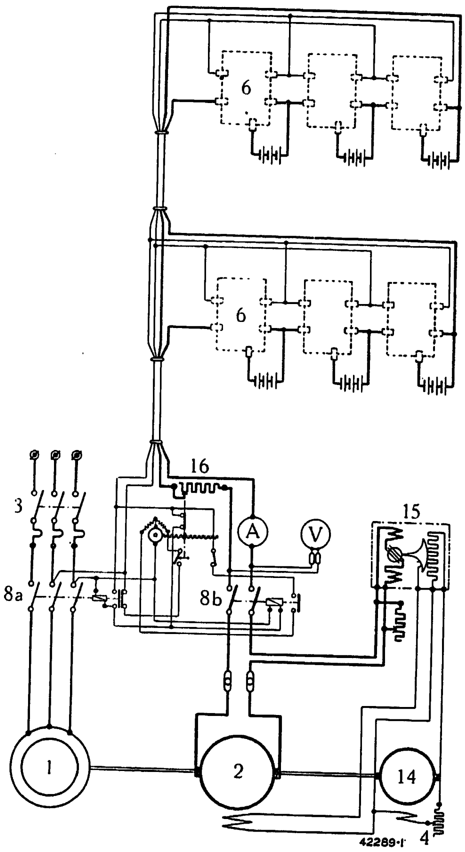


Fig. 5. — Charging equipment for non-stationary batteries (for semi-automatic service).

IV. Several charging points; charging in series with common current regulator.

IV. *Semi-automatic charging equipments with several charging-points according to diagram Fig. 5.*

The batteries are connected in series, so that there is only a single charging circuit. The voltage of the charging-current circuit is so regulated, automatically and without losses by the Brown Boveri quick-acting current regulator 15, that the charging current remains constant, independently of the number of accumulator cells in series and their state of charge. As there are no resistances substituted for the batteries which are cut out during the charging process, the equipment works constantly under the most advantageous efficiency. The batteries must, however, be of about the same current capacity, as the same current flows through them all. On the other hand, batteries of quite different numbers of cells can be charged at once. From the point of view of operating safety, the number of cells in series must not be excessive. For this reason, it is obvious that this layout is best suited for the charging of batteries having a small number of cells, such as, for example, signal, laboratory and automobile batteries.

Each separate battery has its current-compounded charge limiter 6, which also serves as a battery switch, here, having reinforced special contacts. It assures very precise limiting of the charge for batteries having a small number of cells. Each of these charge limiters has a main change-over contact which cuts out the battery, on one pole, once charging is accomplished, without breaking the charging-current circuit of the other batteries. The auxiliary contacts of the charge limiters are connected in parallel and serve to connect up the charging set when the first battery is connected, and also to cut out the said set when the last battery has been charged. The contactor 8b which closes and opens the charging circuit and is actuated by the supply voltage, protects the charging generator against reverse current when the supply voltage fails. In order to eliminate current surges

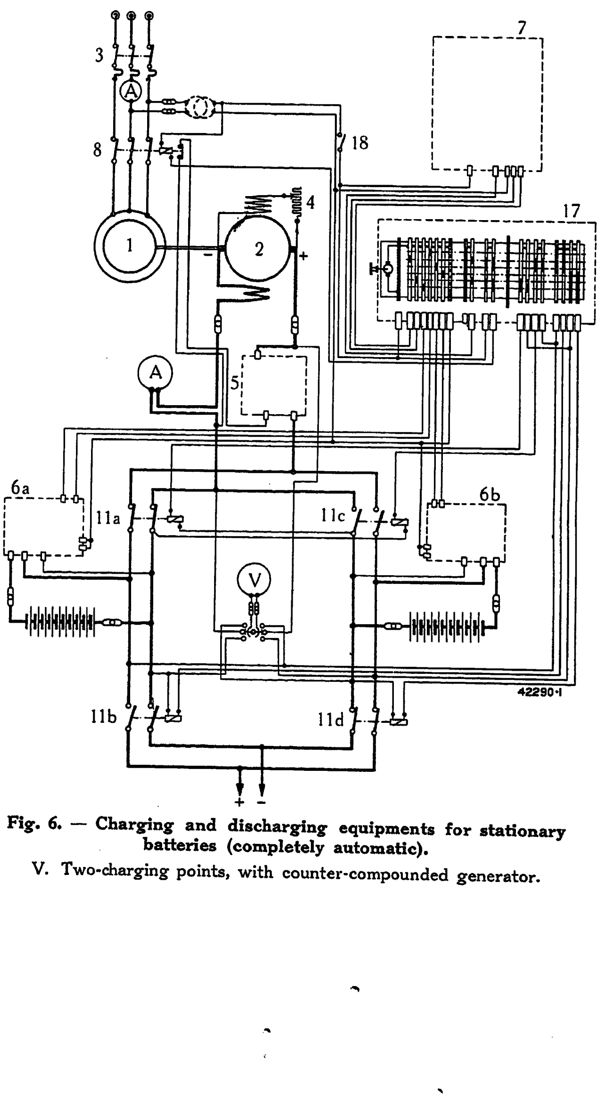


Fig. 6. — Charging and discharging equipments for stationary batteries (completely automatic).

V. Two-charging points, with counter-compounded generator.

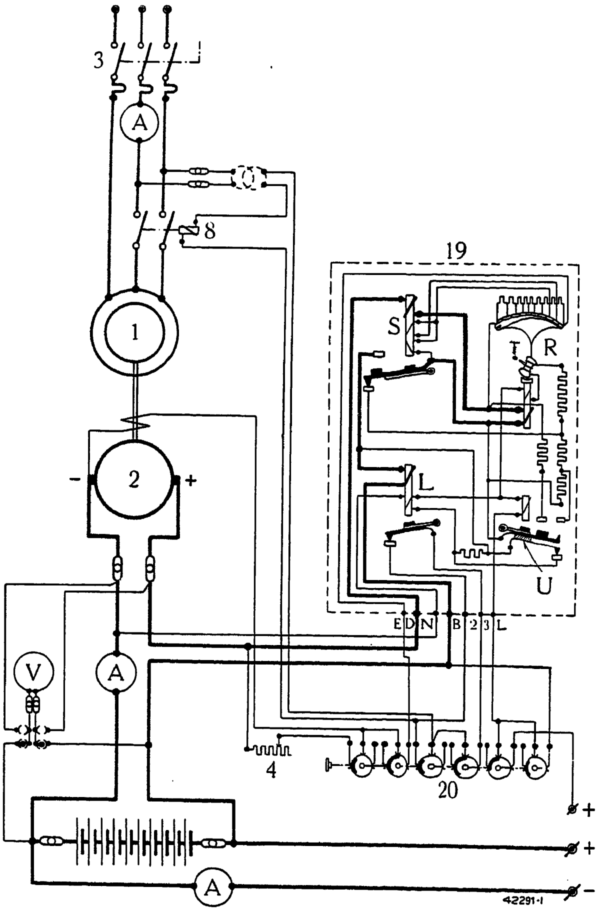
when the generator is switched in, there is a switching-in resistance 16 inserted on the charging-current circuit, which is short-circuited shortly after the charging-current circuit has been closed. In the meantime, the current regulator has so regulated the generator voltage that the batteries absorb the proper current. Attendance is, thus, limited to connecting the batteries to the corresponding charging points and to releasing the catch of the corresponding charge limiter 6.

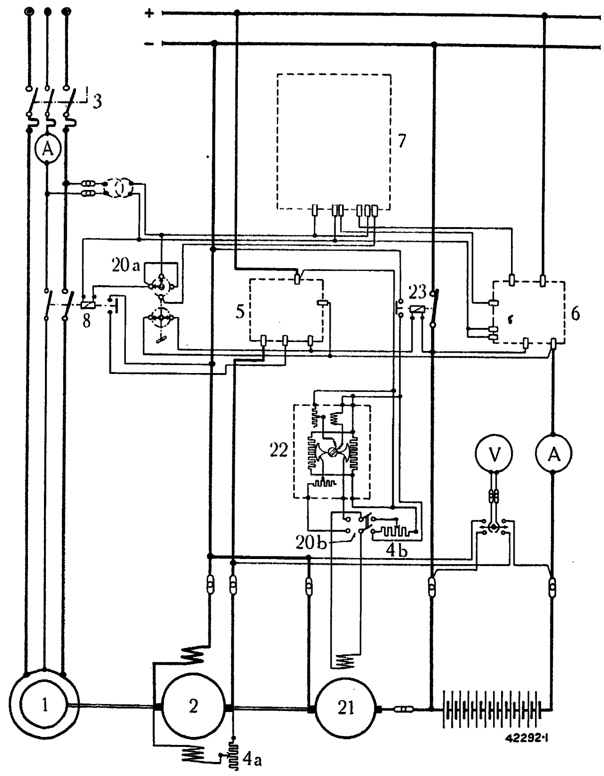
It is, therefore, possible to place the charging points in different rooms; for example so that the charging group is lodged on the cellar level while there are connecting points for the batteries on the different floors.

B. *Stationary batteries.*

V. *Completely automatic charging and discharging equipments with two charging points, according to Fig. 6.*

This equipment is used for *alternative charging and discharging of two batteries.* One of the batteries is always connected to the D. C. system, while the other is either being charged or is lying idle in fully-charged condition, so as to be able to take over the supply of the D. C. system in the place of the first battery, as soon as the latter is discharged down to the admissible limit. The change-over of the batteries takes place without interruption of the voltage on the D. C. system. The charging process and the connecting up and cutting out of the charging set is similar to the arrangement given under I, according to Fig. 2. The charge and discharge limiter is composed, per battery, of a current-compounded maximum and minimum voltage relay 6a and 6b, and of the common automatic inter-





Figs. 7—8. — Charging and discharging equipments for stationary batteries (completely automatic).

VI. One charging point with charging regulator. VII. One charging point with auxiliary generator (booster) and voltage regulator.

Common legends for Figs. 2—8.

1. Three-phase motor.
2. D. C. Generator.
3. Three-pole switch.
4. Sliding resistance.
5. Reverse-current voltage relay.
6. Current-compounded maximum and minimum voltage relay.
7. Intermediate relay.
8. A. C. contactor.
9. Field rheostat.
10. Series resistance.
11. D. C. contactor.
12. Connection box with plugging device.
13. Current-limiting regulator.
14. Exciter.
15. Current regulator.
16. Switching-in resistance with motor drive of sliding contact.
17. Change-over relay.
18. Auxiliary switch.
19. Charging apparatus with change-over relay U, maximum and minimum voltage relay L, quick-acting voltage regulator R, reverse-current voltage relay S.
20. Change-over switch.
21. Auxiliary generator.
22. Quick-acting voltage regulator.
23. Battery switch.

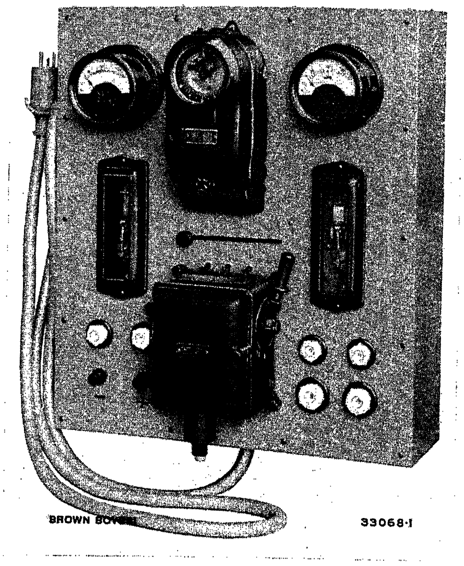


Fig. 9. — Wall-type switchboard panel of semi-automatic charging equipment with one charging point.

mediate relay 7. The change-over relay 17, which can also be hand-operated actuates the switching in and cutting out of the batteries and of the charging set. The completely automatic charging and discharging equipment is designed *specially for automatic telephone central stations.*

VI. *Completely automatic charging and discharging equipments according to Fig. 7.* These equipments allow of *charging a battery when the D. C. system is idle, and of supporting the battery partly or completely, by parallel operation with the generator when the D. C. system is working.*

The generator must, thus, work to two voltage ranges. In Fig. 1 A a, the straight line A represents the voltage-current characteristic during charging, the straight line P, the voltage-current characteristic during parallel operation. As soon as current consumers are connected to the D. C. system, the change-over relay U causes the charging set to start up, this through charging-voltage relay L, causing the closing of contactor 8. At the same time the change-over relay U connects the Brown Boveri quick-acting voltage regulator R for parallel operation of generator and battery. As soon as the generator produces a voltage of about the same value as the no-load voltage of the battery, the reverse-current voltage relay S closes the main circuit. The generator voltage is regulated by the voltage regulator R according to characteristic P, for parallel service. When the last consumer is cut out, the change-over relay U sets the voltage regulator R to charging, so that the generator voltage now follows the curve corresponding to characteristic A. When the battery is completely charged, the current-compounded maximum and minimum voltage relay L opens motor contactor 8 and, therewith, the current circuit of the motor. The reverse-current voltage relay S cuts off the generator from the battery when the reverse current begins to flow. The maximum and minimum voltage relay L, however, does not only serve to limit the charge, but to limit the discharge of the battery, as well, this by falling back when the battery has reached a certain discharge point, and by, thus, starting up the charging set through closing motor contactor 8. With the help of change-over switch 20, the set can be started up or cut out by hand and the different generator voltages set by the sliding resistance 4.

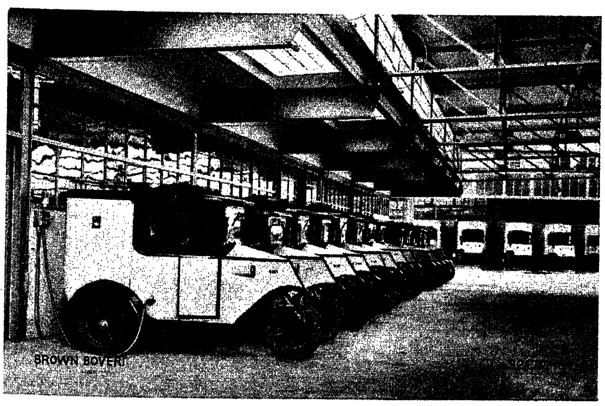


Fig. 11. — The new head post-office building (Sihlpost) Zürich. Charging points for electric vehicles.

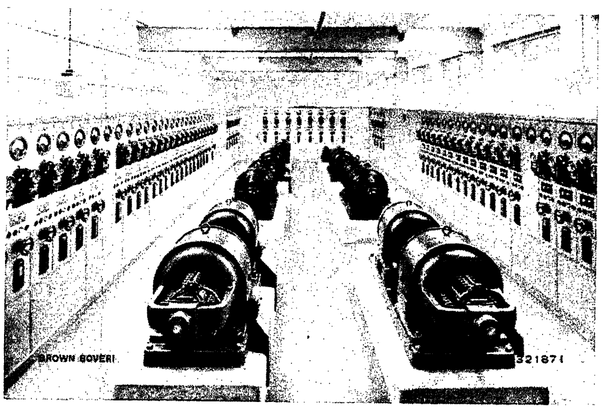


Fig. 10. — The new head post-office building (Sihlpost) Zürich. Switchboard plant for a semi-automatic charging equipment with several charging points.

The switching and regulating apparatus as they are combined in the complete charging apparatus 19, can also be used for charging and buffer equipments, the generators of which are subjected to wide speed fluctuations, for example in train and marine lighting plants in sets with petrol, Diesel and wind-driven motors or in small hydraulic and steam turbine-driven sets.

VII. *Completely-automatic charging and discharging equipments according to diagram Fig. 8.* This equipment is meant for *supplying a D. C. system at constant voltage with simultaneous and automatic charging of a battery.*

The connections are such that the D. C. system is not left without voltage when the charging set is being connected or cut out. The converter set is composed of a motor 1, a main generator 2 and an auxiliary D. C. machine 21. By connecting the two D. C. machines in series a voltage partition is realized,

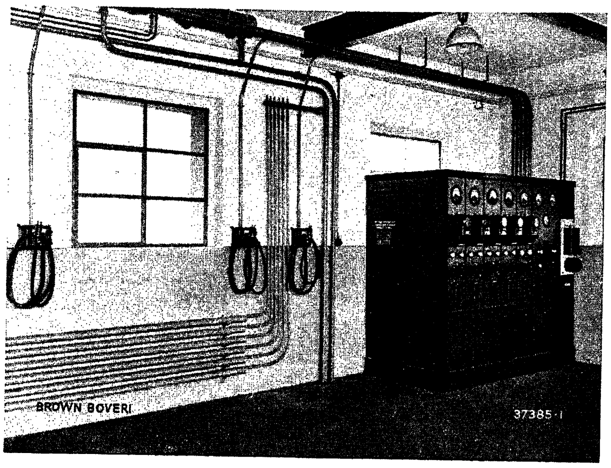


Fig. 12. — Switchgear plant and charging points for a semi-automatic charging equipment with several charging points.

so that the main generator maintains the D. C. system under voltage, while the auxiliary D. C. machine generates the voltage requisite to charging and discharging.

The battery is continuously supervised by the Brown Boveri charge and discharge limiter, composed of the current-compounded maximum and minimum voltage relay. The set is started up automatically by the closing of the contactor 8, as soon as the battery has been discharged down to a fixed point. The reverse current voltage relay 5 connects the main generator to the system, when its voltage has attained that of the battery, and, at the same moment, opens battery switch 23. The current circuit of the battery now passes through the auxiliary generator 21, which is so regulated by the voltage regulator 22 that when the system carries a light load, the battery is charged, and that it is discharged when the load on the system is heavy. The system voltage remains constant, so that the main generator always delivers the same output if its excitation is not modified. Thus the main generator 2 can be designed for an average loading current at constant voltage, while the auxiliary generator 21 is dimensioned for the charging and discharging current and the corresponding boosting and counter-voltage.

As soon as the battery is charged, the charge and discharge limiter 6 cuts out the set. Simultaneously, the battery is connected up again to the D. C. system by the closing of the battery switch 23.

In plants with systems carrying a steady load, with possible overloads of short duration, a similar but simpler equipment, without quick-acting regulator can be used. The feature of this equipment is that the battery is constantly charged as long as the set is running. The auxiliary generator produces the extra-charging voltage while the main generator, by suitable compounding, maintains constant line voltage and provides both charging and line current.

The equipments described allow of eliminating battery switches, so that the cost of the plant is reduced on account of there being neither regulating cells or battery switch. Further, attendance is considerably simplified and the length of life of the battery increased, as all the cells carry the same current, i. e. are uniformly discharged and charged, and insufficient charging or discharging of individual cells does not occur.

Equipments with suitably connected Brown Boveri quick-acting regulators, similar to Fig. 8, find a variety of applications for *voltage, current and power regulation in systems; further, for power compensation (buffer duty) between different systems.* Services of this kind can generally be made entirely automatic with the help of our well known quick-acting regulator, while maintaining very great precision and reliability.

The object of these paragraphs is to give a short summary of the most common connections and uses

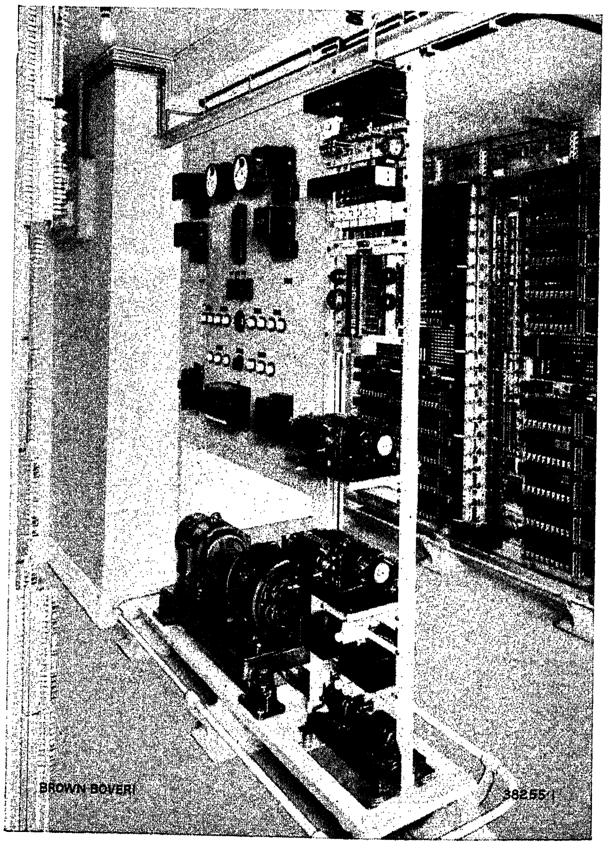


Fig. 13. — Completely automatic charging and discharging equipment with two charging points, for telephone batteries.

of charge and discharge equipments of storage batteries. It should, however, be added that thanks to the adaptability of the Brown Boveri apparatus and equipments the most suitable solution for exceptional and individual operating requirements can always be found.

(MS 989) *M. Steinebrunner. (Mo.)*

A MODERN SEMI-PORTAL LUFFING CRANE IN THE HARBOUR OF KLEINHÜNINGEN ON THE RHINE NEAR BASLE.

Decimal index 621.34:621.873.3.

THE increase in transit traffic through the Basle harbour on the Rhine caused the Neptun Transport und Schiffahrts A. G., Basle, to acquire a third crane to be added to the two they already possessed.

In order to handle heavy peak duty, which is often called for, a crane of very adaptable qualities was required. A portal crane, the upper part of which could be slewed and with a luffing jib was chosen, which could cover a big loading area without being displaced. It was designed and built by the Demag A. G., Duisburg (Fig. 1). This interesting plant is described in some detail in the following paragraphs, special attention being given to the electric equipment with the new Brown Boveri hoisting control gear for standard three-phase induction-motor drive, for which a patent has been applied.

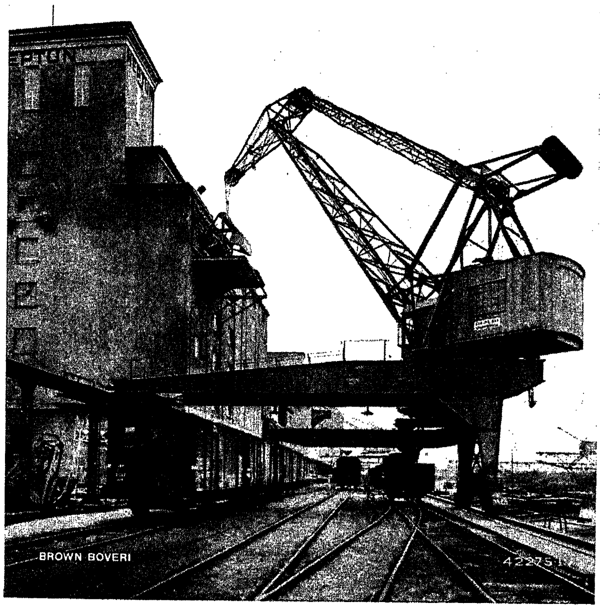


Fig. 1. — Semi-portal, luffing crane belonging to the Neptune A. G., Basle. General view with grain hopper.

The following is the chief data on the mechanical part of the crane plant:—

Hoisting capacity	5 t in grab service
Portal span	16·56 m
Maximum lift	30 m
Maximum radius	20 m
Minimum radius	8 m
Hoisting speed	70 m/min
Grab-closing speed	70 m/min
Luffing speed	60 m/min
Slewing (rotating) speed	1·5 times per minute
Speed of portal displacement	25 m/min.

The crane plant is composed of a semi-portal on which the upper, slewing part is mounted. The *semi portal* is in closed-partition design; there are four running wheels in the supports on the water-front side and three on the land side. Only the four former are driven.

The *slewing upper part* of the crane is carried by four rotation rollers resting on the rail ring of the portal. The platform of the rotating part is a welded design which carries both slewing and hoisting machinery.

The *hoisting gear* is of special Demag winch-gear design in which the grab-closing and the holding drum are coupled together through a planet gear. These winches have two motors:— the hoisting motor which carries out hoisting and lowering of the grab, either, full or empty, and the closing motor which performs the closing and opening of the grab. The latter movements can be carried out during hoisting or lowering by insertion of the planet gear.

The *luffing gear* is an interesting design, luffing being performed by a double jib in such a way that the load and the rollers on the outer end of the jib move in a horizontal plane.

In order that the crane may be utilized to the full for heavy duty, the electric driving gear must be so chosen that it can stand up to the considerable stressing imposed. In order to attain speed regulation over a wide range especially for the hoisting winch, it was necessary to provide an electric braking connection. Some details are given in the following paragraphs on the electric equipment delivered by Brown Boveri, beginning with the most important drives, namely the hoisting and the grab-closing gears.

The *hoisting and grab-closing gear* is composed, as said before, of a special type of winch formed of a planet gear on which the hoisting motor and the closing motor work. The hoisting motor is a standard induction motor with a slip-ring rotor, of about 70-kW output, with 50 % switching ratio. The speed is about 750 r. p. m. The grab-closing motor of similar design is of 40-kW output with 15 % switching ratio, the speed being about 750 r. p. m. The hoisting torque of both motors is 2·5 times the standard torque. As the grab-closing motor is only in circuit for a short time, during closing and opening operations of the grab, the short switching ratio of 15 % is allowable.

The motors in question as, in fact, all crane motors which have to be frequently started up, have constantly-applied brushes. The motors have roller and ball bearings which call for very little attendance. To control the motor, that is for starting, reversing, electric braking and stopping a *cam type of controller* is used for the bigger hoisting motor while the smaller grab-closing motor has a drum type of controller. The cam controller has block contacts

which come together with hammer-like action at switching in, while, at cutting out, the block contacts are forced apart by suitably shaped cam pieces. Each contact point has its own magnetic arc blow-out which leads to very perfect circuit-breaking conditions and slight wear from burns.

These *cam controllers* (Fig. 2) have given excellent results after years of operation under the severest conditions. A great number of switchings can be carried out before the contacts have to be changed, about one million, in fact. If, for example, there are 400 switchings per hour and if the working time is 10 hours per day, it will only be found necessary to change some contacts after about a year. It must be stressed that, until the time the contacts are changed, no tiresome attendance etc. is required for the cam controller. All that is needed is that the copper dust which collects in the inside should be blown away, at rare intervals. Drum controllers, on the contrary, must be supervised several times every month, which generally means that various burnt-out contact parts have to be replaced. Experience shows that cam controllers call for so little spare material or attendance that they quickly repay the additional primary output spent on them.

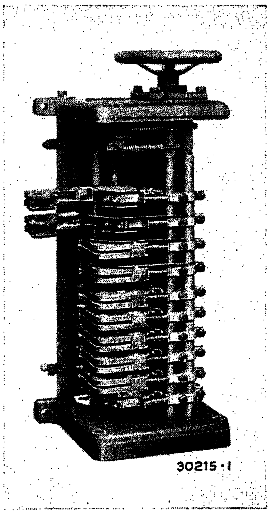


Fig. 2.— Cam controller with handwheel. Shield raised.

All moving parts of the cam controller are in ball bearings. Combined to a Brown Boveri patented compensating device, the controller is very easy to operate and it is rare that the engine-operator experiences fatigue even under the severest crane service.

On the subject of the *drum controller* to control the smaller grab-closing motor there is little to say, as it is of a design generally known in which the contact fingers run on and off segments mounted on a contact drum. It should be said, however, that ingenious design and construction of the contact fingers have allowed of reducing the burns to the minimum attainable with drum controllers and that burnt parts can be very rapidly replaced.

The drum contact segments as well as the sparking pieces on the contact fingers are generously dimensioned (Fig. 3). The hoisting controller is actuated by a big handwheel, in the present case. Fig. 4 shows the hoisting controller on the right-hand side and a part of the handwheel. The grab-closing controller is also seen; it is on the left-hand side, next to the window, and has also got a handwheel.

There are resistances with cast-iron elements for starting, for speed regulation and braking. These are specially designed for the severe service conditions of crane work. These resistances are amply dimensioned and allow of speed regulation over long periods, as is necessary in crane operation.

For the *hoisting and closing mechanism* a *special breaking connection* is used. This is a quite novel arrangement allowing of lowering loads with induction motors, below the synchronous speed, that is at speeds lower than the rated speed. It should be of interest to give some details on this connection, a patent for which has been applied for by Brown Boveri.

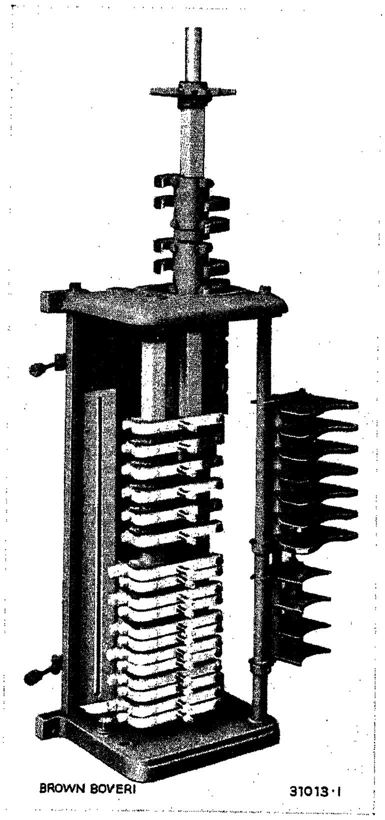


Fig. 3.— Drum controller, shield raised, spark blow-out device turned back, contact drum raised.

In loading plants operating with grabs as well as in those handling separate goods, the principle

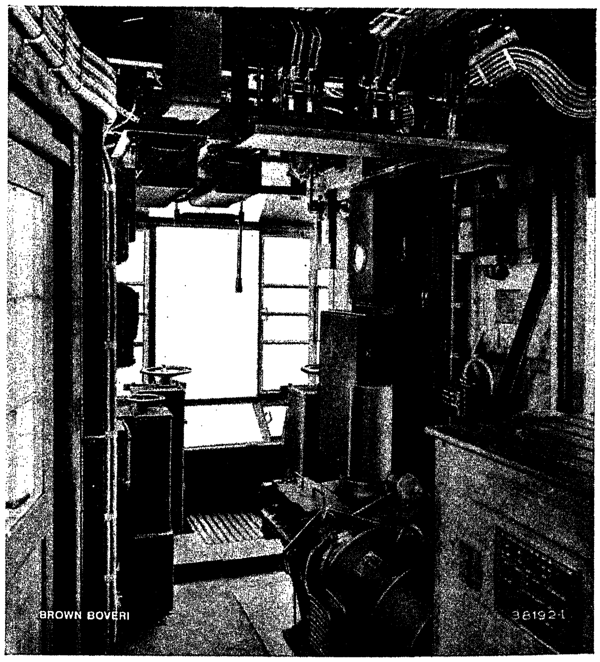


Fig. 4.— Driver's cab of semi-portal, luffing crane of the Neptune A.G., Basle.

duty, apart from hoisting, conveying and slewing, is to lower and deposit the load in absolute safety. While hoisting does not offer any particular difficulty, special measures are required for lowering heavy loads to prevent running away. The lowering-braking connection, used for many years, leads to all kinds of difficulties. It is true that it is possible, with the help of special types of motors, to attain speed regulation over a wide range even when lowering weights, i. e. electric braking. This is the case for commutator motors, for example. With standard induction motors, however, which are so much appreciated owing to their simplicity, there was no possibility of speed regulation when lowering weights at speeds below that corresponding to synchronism. It is true that a certain degree of regulation was possible by counter-current braking, i. e. by changing over two phases, but the double rotor voltage generated by this method and the heavy mechanical and electrical shocks are all undesirable factors. In order that the said shocks be limited to allowable values, it was necessary with the system of counter-current lowering-braking connection to have recourse to certain safety measures, such, for example, as inserting big series resistances in the rotor circuit which, of course, made the whole connection system highly uneconomical. A further disadvantage is that, once the braking process is over, the load often moves in counter sense, i. e. is hoisted again, because exact adjustment of braking torque to load torque is a very difficult matter. It is, therefore, necessary to insert a load-hoisting preventive device in order to attain good working conditions. In order to prevent the free fall of the loads, there must be special measures taken to eliminate the free-fall position which is an inherent character of counter-current braking. All these measures make this system of connections expensive and uneconomical and render it difficult to supervise, as well, which often is the cause of long interruptions in service.

Apart from this counter-current connection, the induction motor can be used for another kind of braking, this being the super-synchronous lowering-braking connection. In this case, the descending load drives the motor at speeds above synchronism and power flows back to the system. These super-synchronous lowering-braking connections are fairly generally known and need not be described in more detail, here. As their name implies, they allow load lowering at super-synchronous speeds, that is to say faster lowering than that corresponding to the rated speed of the motor. There can, however, be no regulation of speed in the sub-synchronous range, that is, below the speeds corresponding to synchronism.

The new *super- and sub-synchronous lowering-braking connection with a reversible phase* developed by Brown Boveri allows of lowering the load at a speed higher than that corresponding to synchronism and, as the name implies, it permits of handling loads being lowered at sub-synchronous speeds, that is speeds below that corresponding to synchronism. Fig. 5 shows how the stator winding of the standard induction motor is connected up to the supply system for hoisting, for lowering under power and lowering under braking, where this new connection is used. The figure shows clearly how simple the connection is and in passing from lowering under power input to lowering with braking, a stator phase is simply changed round by 180 electric degrees. By the simple exchange of the terminal connection of a stator phase, not only is braking effect introduced, however, but asymmetry of the stator currents. If, however, switching is carried out over a single-phase series resistance in a corresponding phase, this asymmetry can be eliminated and the current maintained about equal in all three phases. The series resistance is the only additional apparatus in this new lowering-braking connection. This three-phase regulation is, thus, quite simple in design, and reliable in service, while maintaining the good qualities found in the best-known control systems.

The connection allows of smooth changing over at little current expense and braking at super- as well as sub-synchronous speeds, i. e. the load can be allowed to travel fast over long distances and then be braked electrically. Where careful lowering is essential, as happens in lowering into ship holds, for example, or loading railway trucks, only those braking steps are used which allow of moving the full load at a smaller and controllable speed. The new connections allow such a wide margin of speed regulation, that it is even possible to keep the full grab suspended on the braking positions; this is not usually necessary. The braking effect is thus strong and is easy to regulate over a wide range without requiring the heavy resistances which have to be used in ordinary counter-current braking systems. In all cases, the braking current does not vary much.

Fig. 6 shows the fundamental diagram of connections of a control connection of the kind described. In switching over from braking to lowering with power input or vice versa, the magnetic field does not vanish; there is, therefore, no free-fall position.

In the hoisting gear of the Basle loading crane, this lowering-braking connection has been applied in conjunction with a cam controller with hammer contacts. The control can, however, be used in conjunction with drum controllers or else with a master drum and contactor control. The new braking connection is suitable for the drive of luffing gears and conveying mechanism as well as for hoisting and grab-closing. Fig. 7 shows the characteristic curves of the new sub- and super-synchronism lowering-braking connection with reversible phase. Fig. 8 shows the

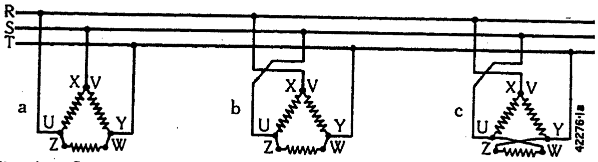


Fig. 5. — Stator connections of the new super- and sub-synchronous Brown Boveri, lowering-braking connection with reversible phase.
a. Hoist. b. Lowering with power input. c. Lowering braking.

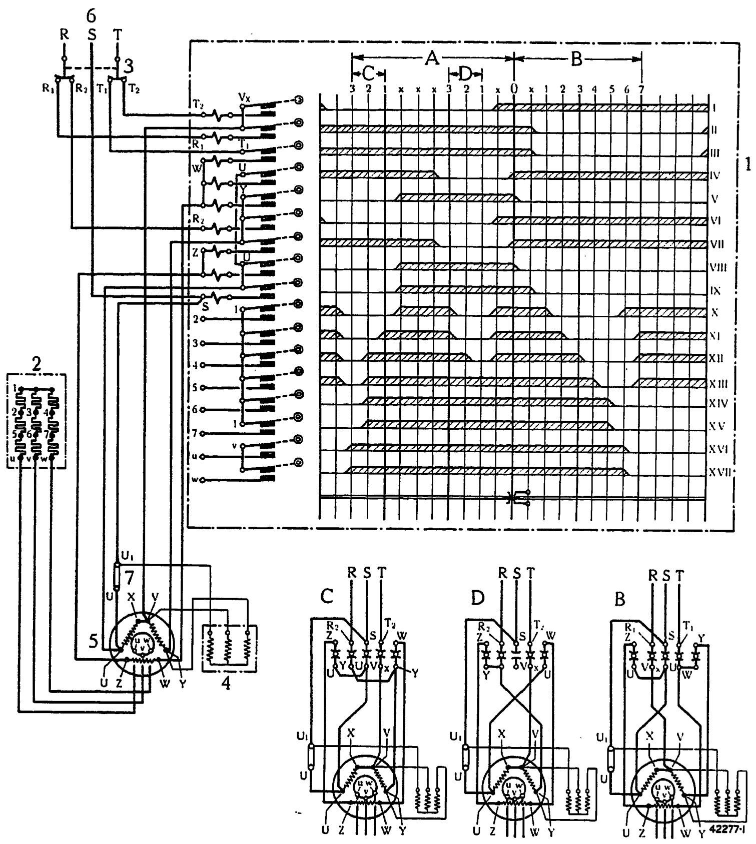


Fig. 6. — **Cam controller. Diagram of connections for the new super- and sub-synchronous Brown Boveri lowering-braking connection with reversible phase.**

A. Lowering. B. Hoisting. C. Lowering with power input. D. Braking.

curves of the standard counter-current lowering-braking connection made use of up till now. A comparison shows that the new Brown Boveri connection produces considerably improved speed and torque curves and gives a wide range of regulation, qualities required for crane operation. A large number of cranes have been equipped with the new Brown Boveri control connection and have given excellent results.

A few words will suffice for the other drives of the crane, these being mostly standard equipments.

Demag chose their own patented motors with displaceable armatures for the drive of the *travelling gear of the portal or gantry,* these motors were not delivered by Brown Boveri. The gantry travelling motor which, as was mentioned before, acts exclusively on the four roller wheels on the water-front side, develops 7·5 kW with 25 % switching ratio, the speed being 950 r. p. m. The motor is regulated by a drum-type controller with handwheel combined with a starting resistance. The controller is seen, on the left, in Fig. 4 on a bracket and close to the grab-closing controller.

The motor for the *luffing gear* is of 6 kW output with a 40 % switching ratio, its speed being 950 r. p. m. The drum-type controller belonging thereto is actuated by a universal-type control which is also used to control the slewing controller. The output of the motor driving the luffing gear is very low, thanks to the whole jib gear being perfectly balanced by counterweights, so that there are, practically, only friction resistances, acceleration and windage forces to be overcome.

For the portal or gantry drive the braking connection, already described, was also used, but designed as travelling braking connection to allow of braking electrically in both senses before stopping.

The motor for driving the *slewing gear* is of 13 kW output with a 40 % switching ratio, speed 950 r.p.m. It is a standard open-type motor with roller bearings, developing a high starting torque. The latter is equal to about 2·9 times the rated torque. The drum controller belonging to this motor is, as already said, connected to the controller for the luffing gear through a universal-type control. These two controllers are secured to the roof of the crane cabin and, in its neutral position, the control lever of the universal

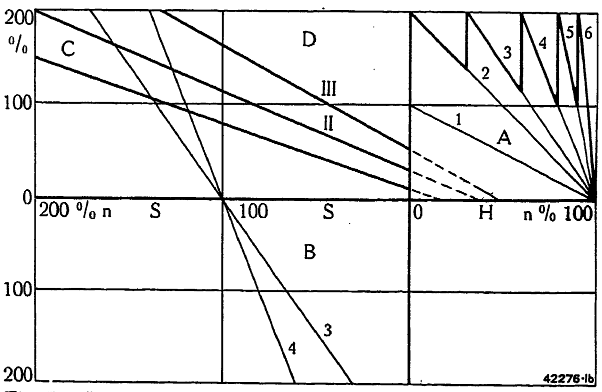


Fig. 7. — **Power and braking curves of the new Brown Boveri sub- and super-synchronous braking connection with reversible phase.**

A. Hoisting. B. Power lowering. C. Super-synchronous lowering braking. D. Sub-synchronous lowering braking with change-over phase.

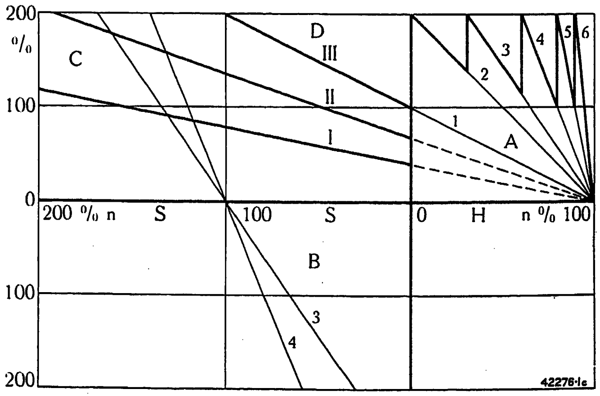


Fig. 8. — **Power and braking curves with standard type of control with counter-current braking.**

A. Hoisting. B. Power lowering. C. Super-synchronous lowering braking. D. Counter-current lowering braking.

control projects vertically downwards (Fig. 4). If this lever is moved to the right or left the controller of the slewing gear is actuated and the crane slews round to the right or to the left respectively. If the control lever is moved forward, that is towards the window, the luffing jib moves outward and, if the said lever is moved in contrary sense, the jib moves inwards. Thus, with a hand lever of the universal control, it is possible to control two drives according to natural control and this without changing the grip on the lever. The universal control combined with the happy layout in the driver's cab makes for easy crane operation without fatigue for the driver.

All drives have, of course, the necessary *protective devices,* apart from the apparatus described, in order to protect the motors from inadmissible overloading. Further, there are end-travel switches to limit the movements of the individual drives to the end-travel positions. All safety and control apparatus is easy to supervise and very accessible, which increases the service reliability of the plant. The whole electric plant is for three-phase, 500 V, 50 cycles.

The crane has been working for a considerable length of time and has given complete satisfaction.

(MS 988) *E. Altschul. (Mo.)*

NOTES.

Some comments on the erection, setting to work and maintenance of turbo-machinery.

Decimal index 621. 757.

It should be of interest to a wide circle of readers to get some closer information on the field defined by the above general heading. Unfortunately, it occurs all too frequently that at the very beginning of the erection of big machines such as turbo-sets with their piping, pumps, coolers, etc. difficulties are encountered which could easily have been avoided by a more efficient organisation and by suitable measures being taken in time. The following paragraphs are some short comments on the erection, setting to work and maintenance of machines delivered by Brown Boveri, without any claim being made to have covered the whole subject or to have reached conclusions which can be universally applied. Every erection can be said to be a problem in itself, which must be tackled and solved independently. The following remarks should, thus, be considered as general suggestions and directives.

The most important points regarding the erection work to be carried out are, generally, fixed during the sales negotiations, that is to say it is determined in advance whether the client will leave the erection of his machine to the manufacturer against a lump sum payment (bulk-tarif erection) or else have the erection carried out at fixed rates (erection on a time basis).

The preparations for carrying out an erection are begun by the manufacturer long before the erector appears on site of the erection. It is obvious that the manufacturing firm must have available a staff of efficient erectors from which they can choose a reliable man for the job in hand. Whenever possible, the erector chosen is made thoroughly acquainted with the set he will have to erect while it is still on the shop test bed, he being employed to assist at the tests, dismantling and adjustment of the machinery before despatch; he also studies in all details the drawings of the whole plant, before he leaves the works.

On the other hand, it is just as important that the client's preparations for the coming erection should be begun in good time, in order that the erection work, once begun, may go smoothly. The "Erection Conditions", a copy of which is in his possession, give the necessary general indications to this end; they stress the importance of having the foundations completed, of having the other building operations properly advanced, of keeping clear the areas to be used to deposit material and of having rooms which can be locked, of preparing gear and lifting tackle, and the small material requisite to all erections etc. and indications as to holding in readiness of assistant labour. For big turbo plants, it is the rule to send an erection enquiry-sheet the object of which is to obtain from the manufacturer useful data on conditions existing on the site of erection and also to make the client acquainted with what conditions should be fulfilled on the said site in preparation for the coming erection.

Experience has shown that it is not advantageous for the client, if material and erection staff are called for too early, that is to say before the material can be unloaded and put in store without hindrance and before erection work can be begun smoothly. It is important that the station building should be so far advanced when the erector appears that windows and doors have been put in, building gear taken away, rubbish heaps removed and the travelling crane for erection, which is either already available or has to be delivered, in running order. If these conditions are not fulfilled, it is, unfortunately, all too probable that the whole erection work will be carried out in an unwelcome atmosphere of delays, of demands and resultant discomfort. Too short delivery time renders erection more difficult; if the various component delivery times of an order are too short, the erection and setting to work, being the last links in a long chain of operations, are very likely to take place under most undesirable pressure as regards time.

The conveyance of the material to below the crane hooks is generally the job of the buyer. In plants where the railway trucks cannot be run directly under the crane hooks, it is advantageous that the necessary facilities for conveyance should be got ready in advance.

The question of the erection crane is worthy of a paragraph to itself. A station overhaulage crane, by means of which turbine cylinder covers, turbine rotors, generator rotors and all lighter pieces can be raised, later on, should, under all circumstances, be mounted and ready for service at the beginning of the erection work. It is, however, very desirable to put up a crane with sufficient lifting power to raise the heaviest parts, as, for instance, the generator stator, even although these pieces have only got to be lifted once, when erection takes place. If another solution is sought for, for reasons of economy, it should always be remembered that, in view of possible future enlargements of the plant, the travelling crane in the station should not be chosen too weak.

The state of advancement of the work on the foundations is of great importance if erection work is not to be hampered. This does not only include foundations for the main set, which work must be carried out exactly to the drawings, as regards elevation and all other dimensions, and which must be built by a competent firm which can be held responsible for the work done. It is just as important that the small foundations, pedestals, etc. to take the auxiliaries such as pumps, preheaters, etc. should be ready when erection begins. It is, precisely, these small foundations which are generally found unfinished when most erections are begun, this although it is very important indeed to be able to erect the auxiliaries along with the main unit, so that work may be begun on the piping. Autogenous welding and electric-arc welding and the use of pipe lengths bent in advance

as well as of welded flanges are all factors which simplify the laying of piping to-day. Nevertheless, the piping demands a big amount of work and the client can contribute greatly to assist this part of the erection by having the right foundations ready in time.

According to erection conditions, each skilled erector is given at least one to two skilled fitters and one to two assistant workmen, according to the kind of work to be done and the extent thereof. If considerable conveying work has to be carried out there must be a suitable group of men engaged for this and available. It is obvious that the quality and willingness of these auxiliary workmen plays a considerable part in the speeding up and smooth carrying out of the erection work.

The erection material to be provided by the buyer must be sufficient in quantity and of first-class quality. This is of vital importance as regards the cables and hemp ropes but applies equally to concrete for grouting, to the cleaning, packing and lubricating material and to whatever firing material is required.

If the erection of the sets follows its normal course, it is important that the buyer should see that the different jobs of work to be carried out by him or by other contractors keep step, as far as possible, with the main erection work. There are often intervals between the end of the erection and the setting to work of the machinery, or else the staff has to be called away and must come back, later, because the other auxiliary work as well as the connections to outside systems for water, steam, air, electricity, etc. are not yet sufficiently advanced. It is the buyer's business to take proper measures in good time. His own works supervisor will endeavour in his own interest, to create harmonious collaboration, on the erection site, between the various firms concerned, in order to reach the ideal aim of having all secondary jobs completed simultaneously.

If, now, all connections to outside systems have been made and if the various materials required for service are to hand in sufficient quantities, a completed machine set can be put into service, without delay. While the machine is being tested, the live-steam piping should be properly insulated and the steam traps tested to see they work properly.

If taking-over tests are to be carried out, the requisite preparations must be made, in good time; there are measuring devices or instruments to be mounted or connected up, and, if necessary, adjustments and cleaning of the machines to be seen to.

It is important that the client's operating staff be made familiar with the new machinery, as far as possible, this as long as the manufacturer's staff is available on site. The instructions for operation delivered with every machine give the necessary directives, in this respect.

It may seem simpler and cheaper to the client to have the periodic overhaulages carried out by his own staff. However, the formation of an independent and reliable erector is a matter of several years. If there are, really, no skilled men of this type available, who are practically and, as far as is necessary, theoretically acquainted with the class of machinery to be handled, it is certainly worth while to have recourse to the manufacturer's own skilled staff for overhaulages. Brown Boveri trained erectors carry out overhaulage work according to carefully drawn up enquiry sheets, the perusal of which means that every individual point gets due attention.

Finally, it should be said that the method of reckoning charges should be subjected to careful analysis, from case to case. In cases of erections carried out for a fixed inclusive price, the client gets information at once from the manufacturer on those parts of the costs which concern the machine erection proper. He must then set down his own estimate of what the costs to him of additional workmen, building work, etc. will be. In many cases it would be more economical to carry out the erection at fixed rates, that is to say to pay the manufacturer's staff according to the time they spend on the job. This saves the buyer having to pay certain risk premiums which every manufacturer is obliged to include in his global price for erection. Further this system allows the buyer a clearer supervision over the progress made on the different working sites of his plant; he is more directly interested in eliminating hold-ups in the work where such occur. This often means considerable saving. The advantages of erection at fixed rates are, therefore, well worth considering, in many cases.

(MS 983) *W. Liechti. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2) : 621. 313. 333.

A three-phase A. C. motor, built for 160 kW, 2750 V, 50 cycles, 3000 r. p. m. was delivered to the "Gemeente Handelsinrichtingen", Amsterdam, in the year 1907. This is a squirrel-cage motor driving a pump, built by Messrs.

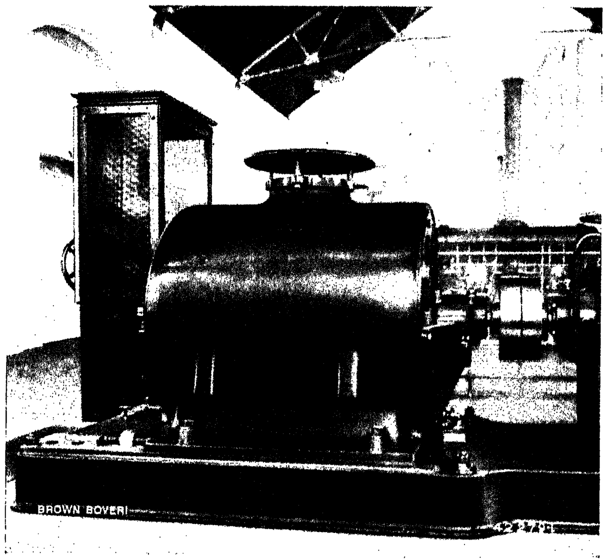


Fig. 1. — Gemeente Handelsinrichtingen, Amsterdam.
Three-phase A. C. squirrel-cage motor coupled to a centrifugal pump built by Messrs. Sulzer Bros., Winterthur, and delivered in the year 1907.

Sulzer Brothers, Winterthur, to which it is directly coupled. The said pump delivers the water under pressure required for the hydraulic hoists of the plant. The requisite oil circuit breaker, starting transformer and over-current relay were delivered along with the motor.

Since this plant was put into service, no major repairs or other changes have been called for and the switchgear apparatus is the identical one delivered 30 years ago.

(MS 991) *Prop.*

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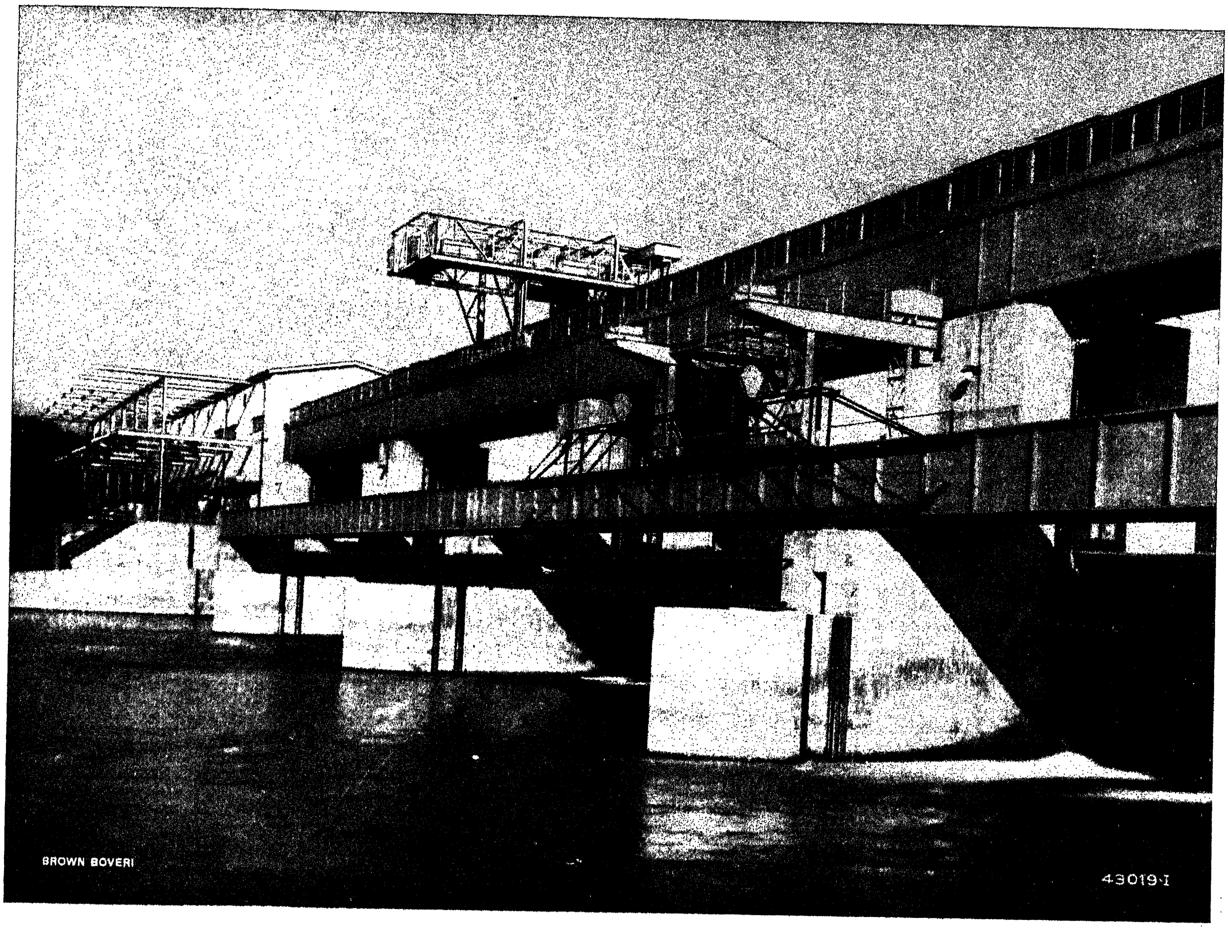
EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



SLUICE-GATE PLANT AND POWER STATION KLINGNAU, SEEN FROM TAIL-RACE SIDE.
View from tail-race side, showing crane for handling coffer-dam parts.

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THE BROWN BOVERI REVIEW

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THE CONVECTOR CIRCUIT BREAKER IN OPERATION ON THE DISTRIBUTION SYSTEM OF WESTERN SWITZERLAND.

Decimal index 621. 316. 57. 064. 25 (494).

THE extensive electric-power distribution system at 130 kV, which supplies the western part of Switzerland, was put into operation in the spring of 1935. Part of the said system was built at an earlier date and had been operated at 60 kV. It was supplied, directly or indirectly, by a great number of medium-sized generating stations such as those of Fully, Martigny, Orsières, Champsec, Sembrancher, Bois-Noir, etc. The building of the high-power Chandoline station, which generates 120,000 kVA and will later be able to produce 200,000 kVA, caused the distribution system to be extended and its voltage to be raised to 130 kV. As the system grew in size, its duties became more onerous. At the same time, service conditions became more exacting, as the system now embraced a great number of important power consumers, the stringent service requirements of whom had, of course, to be satisfactorily met. The most vital of these requirements is continuity of power supply, practically, under all conditions, which implies stability of the distribution system. The latter, in its turn, calls for rapid and certain elimination of faults and satisfactory maintenance of voltage. The protective system of the lines had to be absolutely selective; in other words, only those lines had to be cut out on which defects had occurred. Such a high

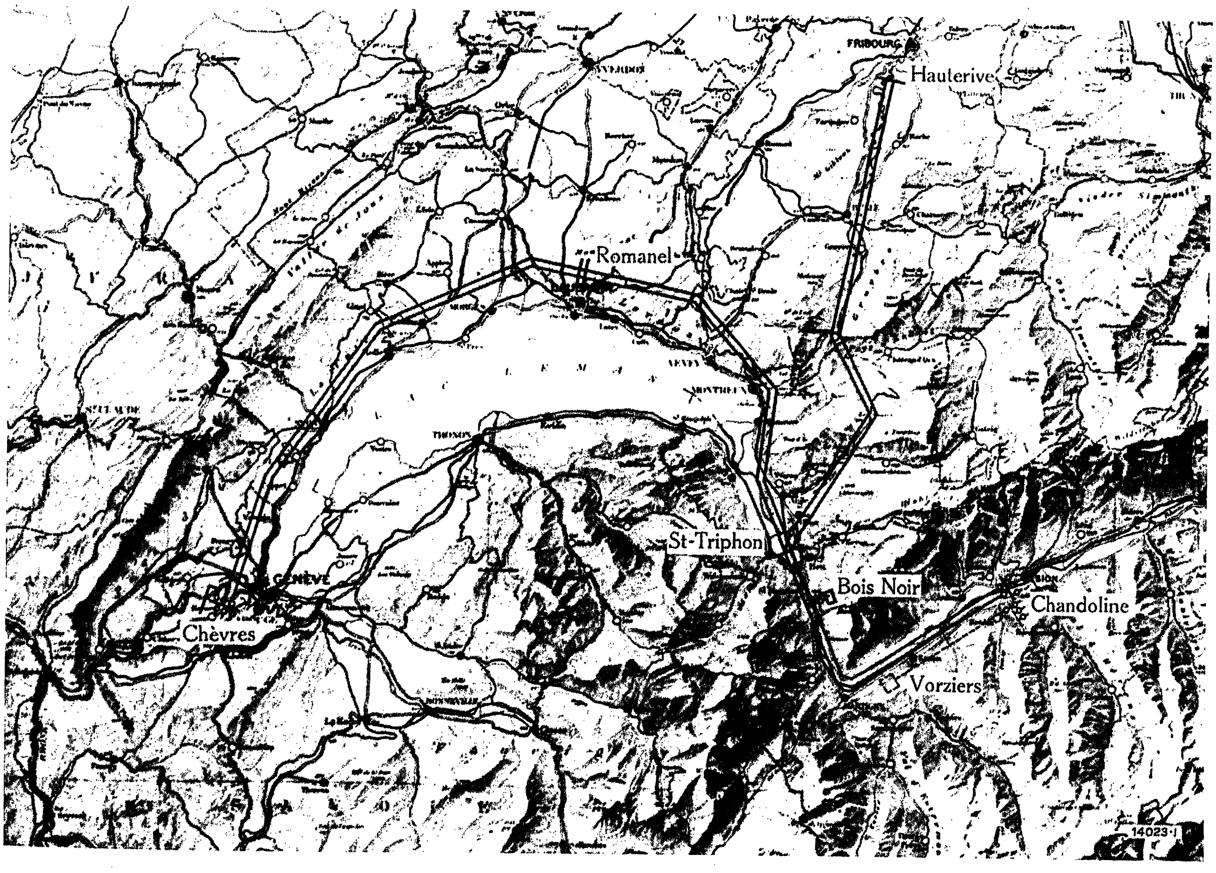

Fig. 1. — The 130-kV distribution system of western Switzerland.

degree of precision in eliminating defective line sections means granting sufficient time to the protective devices to act selectively, and the said time can be made all the longer the quicker the circuit breakers act.

The new distribution system fulfils all requirements as regards stability. Selectivity is assured by means of protection by Brown Boveri distance relays which are extremely precise and have the inherent quality of allowing easy determination of the nature and locality of faults. The rapid cutting out of faulty sections is entrusted to circuit breakers with small oil fillings known under the name of convector circuit breakers. The high-voltage distribution plants of the Chandoline (S. A. La Dixence) power station and of the Bois-Noir (Service de l'Electricité de Lausanne) power station as well as those in the Saint-Triphon (E.O.S. Energie Ouest-Suisse) in the Chèvres (Service de l'Electricité de Genève) substations, Fig. 1, are all equipped with these convector circuit breakers. As regards maintenance of voltage, this is taken care of, chiefly, by the Chandoline power station the alternators of which are equipped with the new Brown Boveri quick-acting high-power regulators.

The distance relays and automatic voltage regulators are well-known Brown Boveri apparatus, while the convector breakers are, relatively, new Brown Boveri products. They were used for the first time in the Chandoline power station equipment, thanks to the far-seeing judgement of Dr. h. c. J. Landry, who recognized their qualities, and they have gained ground rapidly, first in Switzerland and then abroad. They were put into the Chèvres, Saint-Triphon and Bois-Noir stations and, later, into foreign plants. The following paragraphs give some data on these breakers which mark a stage in the development of high-voltage apparatus.

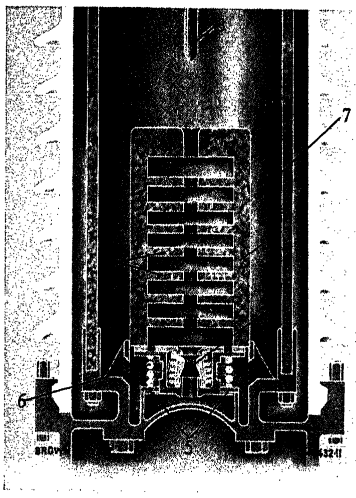

Fig. 2. — Section through a convector.

1. Insulating cylinder.
2. Insulating rings.
3. Rod of the moving contact.
4. Segments of the fixed contact.
5. Valve.
6. Valve spring.
7. Convector chamber.

The convector circuit breaker.

Description. The convector circuit breaker has the external appearance of three separate columns, each of which is composed of two insulators placed one on the top of the other. The lower insulator, conical in shape, forms the base of the column; it is designed to contain precision current transformers. The upper insulator is cylindrical in shape and contains the active parts of the breaker proper. There is a disconnecting switch in series with the latter, the only duty of which, however, is to increase the dielectric strength of the apparatus. The active part of the breaker, oil-immersed, is composed of the moving and the fixed contact and of the convector. The latter, Fig. 2, is an elastic chamber subdivided into cells. It comprizes an insulating cylinder 1 in the interior of which there are insulating discs 2 with holes in their centre, spaced one from another by rings. These discs and rings form the cells and also the central passage through which the moving contact 3 passes.

The lower part of the cylinder is closed by a valve 5 held on its seat by a spring 6. When it opens, this valve establishes a communication between the interior of the convector and the chamber 7.

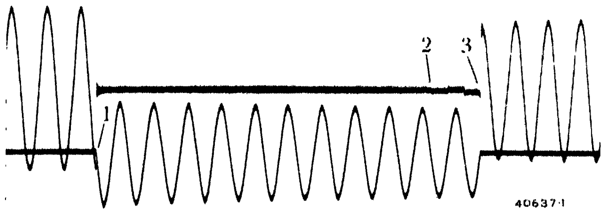

Fig. 3. — Oscillogram of circuit breaker opening.

1. Initiation of the short circuit.
2. Beginning of contact separation.
3. Rupture of the short circuit.

As regards the fixed contact, it is made up of a series of segments arranged in a ring. The contact pressure is produced by a set of springs acting on each of these segments.

Method of operation.—Convection effect causes the arc to extinguish of itself as it creates those conditions which are most advantageous to arc rupture, by using for this purpose the power of the arc itself. At the moment the breaker opens, the arc vaporizes part of the oil in the convector and produces a gas bubble which is in close contact with the oil shut up in the cells. The result is intensive cooling of the gases by convection and consequently of the arc itself. Added to this convection action, there is a kind of flow effect when heavy currents are cut:—as the strength of current increases the development of gases increases with it; the pressure inside the convector grows until it reaches a value at which the valve acts, the valve, once open, allows the gases to escape which they do downwards along

the length of the arc, thus subjecting it to a powerfully deionizing effect. The arc is extinguished in three or four half cycles, as is seen in the oscillogram of Fig. 3, which shows the advantageous curve of the arc voltage. Fig. 4 summarizes a large number of tests and illustrates the development of the arc voltage which follows a parallel curve to that of the pressure. The arc voltage is low in the first half cycles and only increases rapidly in the half cycles before the arc rupture. This feature, allied to a very short duration of arc, combine to reduce to a minimum the power required for arc rupturing. This, therefore, allows of reducing the oil filling to a very low figure, which is 1/30 th to 1/100 th of the quantity required for an ordinary oil circuit breaker. This reduction of oil filling is all the more justified as the oil only plays the part of an extinction medium here, and not that of an insulator.

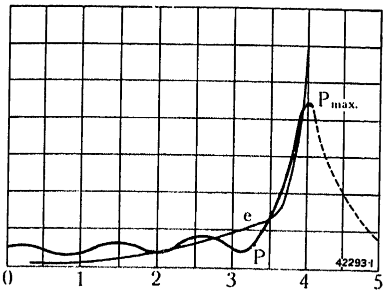

Fig. 4. — Characteristics of arc voltage e and of pressure p in function of time (in half cycles) in a convector.

Auto-extinction is, thus, determined by the convector and its valve. The latter regulates the pressure in the convector to a relatively low value. This value is so chosen that the arc always goes out when the current passes through its normal zero value and that the length of the arc remains practically the same whatever the strength of the current, two features which distinguish the convector entirely from an ordinary explosion pot. Fig. 5 shows the relation between the current strength and the arc length, on the one hand, and the pressure in the convector, on the other. The current characteristic does not reveal any critical value, to be feared in the range of low currents. For heavy currents, the pressure is obviously, slightly higher, the flow effect mentioned above stronger and the length of the arc slightly shortened, for this reason. This means that short circuits will be ruptured rapidly, which is a very desirable quality. Thus, this particular type of elastic chamber, the convector, confers on the breaker the quality of having no zone of ineffectiveness either in the heavy-current range or in the low one. No accessory devices are needed when dealing with low currents, which, thanks to the character of the convector, never create excess voltages by premature rupturing of the arc.

As regards the rupturing time, that is the time counted from the moment the trip coil is excited until that at which the arc is extinguished, it is practically, constant, as well, being of the order of 15/100 of a second. This remarkably short time is due to the lightness of the moving contact parts, the small mass of which offers very slight resistance to the powerful breaker-opening springs and to the pressure of the gases acting in the convector on the moving contact as on a piston. It is with a view to reduce these masses that the insulating disconnecting switch, which has no part in the rupturing process itself, is designed with a separate opening mechanism. The reduction of the moving masses is, also, very advantageous in closing on short circuits which calls for very high speeds in order to hinder an arc starting up which may weld the contacts together. The rapidity of the closing operation is not only a useful factor in closing on short circuits but also in every case of paralleling. It is desirable that paralleling operations should be performed as perfectly as possible that is with a minimum of power exchange between the sections of the system being coupled, in order to eliminate hunting of the generators. These oscillations which react on the regulating organs of the prime movers, as they correspond to exchange of watt power, may cause generating units to fall out of step, and this is, of course, contrary to the stability of service so much desired. Although in the high-voltage range the closing conditions are less severe than in the medium-voltage one, the impedances between the machines to be coupled being greater, it is, nevertheless, necessary that the total closing times of the breakers should be of the order of 5/10 th s. With this closing time it is certain that satisfactory coupling conditions will be observed, and paralleling carried out without too great phase deviation of the voltage vectors on either side of the breaker. It is this phase difference along with the impedance of the circuits to be paralleled which determines the magnitude of the compensating watt powers which flow. Thanks to the small mass of the moving part of the convector circuit breaker, big closing speeds are attained, which are imparted to the said mass by a powerful spring drive. This drive provides the closing energy and the opening energy, as well, as it loads the springs used to produce the opening movement. From a practical point of view, the spring drive in high-voltage breakers, in the most common

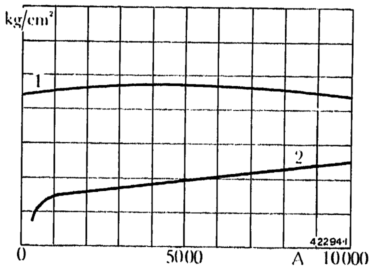

Fig. 5. — Characteristics of arc length 1 and of pressure 2 in the convector, in function of current strength.

case which is that of remote control, has the great advantage of only requiring a small storage battery. This is very advantageous in substations, which have, often, no continuous attendance, and which can thus be designed as a simple shed to cover the protective device, the small battery and its very simple recharging equipment. Further, a spring drive generally allows of making considerable saving in auxiliary pilot cables. Finally, if the circuit breaker has to be closed by hand, for any reason, when under voltage, the spring drive which produces breaker closing in a fixed time, allows of carrying out this operation which always presents a certain element of danger if done by hand alone.

The convector circuit breakers having been described as regards design and operating method, some paragraphs should be devoted to the conditions they work under on the system and to the duty they fulfil.

The convector circuit breaker on the distribution system of western Switzerland.

The new 130-kV system, which is designed with a view to future extensions both in area covered and in number of transmission lines, possesses, at present, two main transmission lines. These take off from the Chandoline power station, pass along the Rhône valley, tapping on the way part of the power generated in the Bois-Noir power station, and end in the Saint-Triphon substation, near Bex (Canton Vaud). The two lines are doubled in Saint-Triphon. One branch passes through the Pays-d'Enhaut and la Gruyère and is carried to the Hauterive station of the Entreprises Electriques Fribourgeoises. The other double line is carried along the side of Lake Leman and is connected, in passing, to the Romanel substation. This double line ends at Chèvres, some kilometres from Geneva.

The raising of the voltage to 130 kV which was carried out when the Chandoline power station was built, was the cause of the building of the Saint-Triphon substation and of the transformation of the Bois-Noir and Chèvres stations. The Romanel substation was designed from the first for 130 V and did not require to be altered. The equipment of the new plants and those modified, which is characterized by convector breaker sets, will be summarily described in the following paragraphs.

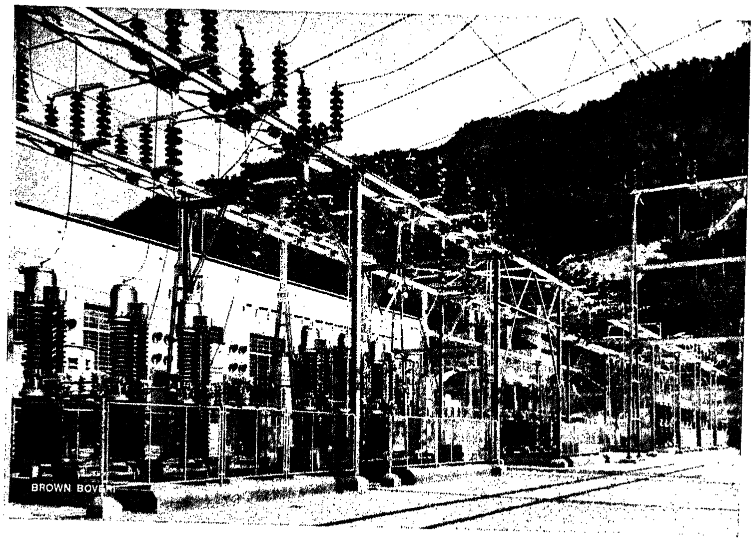

Fig. 6. — Chandoline power station. Outdoor 130-kV station.

The Chandoline power station (S. A. la Dixence). — The high-voltage distributing plant at 130 kV comprises six sets of each three convector circuit breakers (Fig. 6). There are three sets on the 130-kV leads of the main transformers which are built with three windings 13/60/130 kV, and there are three sets controlling the outgoing lines. Of the latter sets, two are on the main outgoing lines 130 kV, while the third is on a connecting line to the Vorziers substation which still operates at 60 kV. Apart from the 130-kV breakers, there are three sets of convector circuit breakers at Chandoline, of the 60-kV type, Fig. 7, for transformer control. All the breakers are mounted close to the ground being secured on concrete pedestals, as

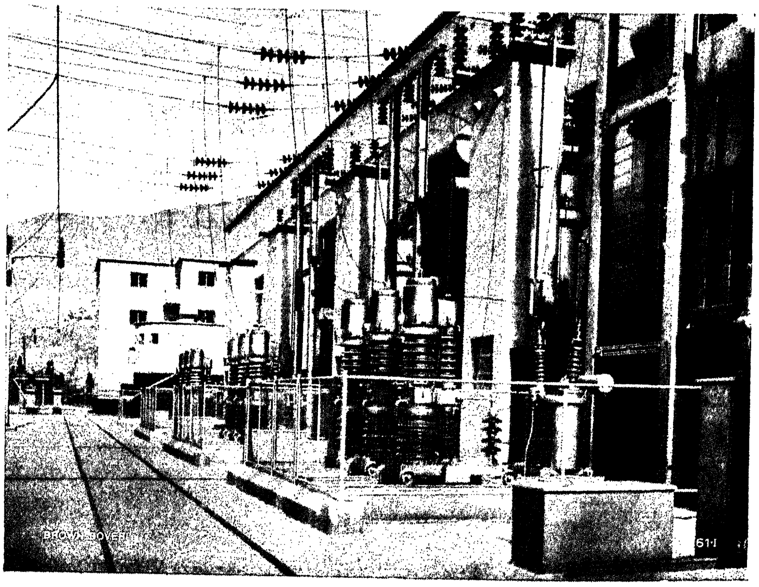

Fig. 7. — Convector circuit breaker, 65 kV.

the illustrations show. Each set of breakers is surrounded by a portable protection grid outside of which is located the control cubicle common to the three phases. This is an economical solution of the erection problem. Carried out with "Differdange" iron work, it is light and makes for easy supervision of the plant.

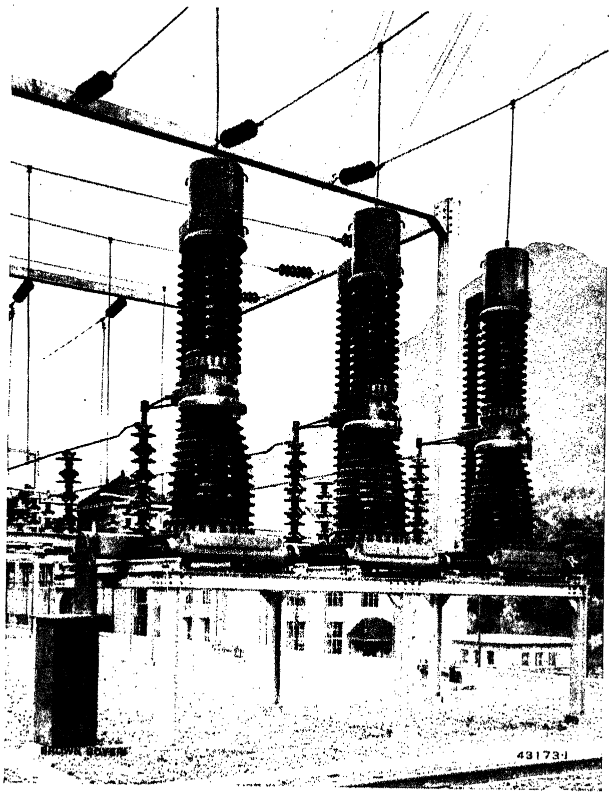

Fig. 8. — Convector circuit breaker in Bois-Noir power station.

The Bois-Noir power station (Service de l'Electricité de Lausanne). — Fig. 8 shows the set of 130-kV convector circuit breakers which connects the power station through a 6/130-kV transformer, to one of the main lines from Chandoline. Contrary to the Chandoline layout, the breaker is mounted on a frame, which was thought preferable here on account of local conditions.

The Saint-Triphon substation (E. O. S.)—When developments are complete, four main lines will come in and be joined up to a double set of busbars and four lines will take off from the latter. At present, there are three breaker sets mounted, two on the two lines to Hauterive while a third will be connected to one of the main future lines. The sets with their disconnecting switches are mounted on the ground level inside protective grids. This is convenient for overhauling the convector breakers which do not require any special building for this purpose. The substation is only provided with a small house, just big enough to hold the relay panel with the distance relays, and the storage battery.

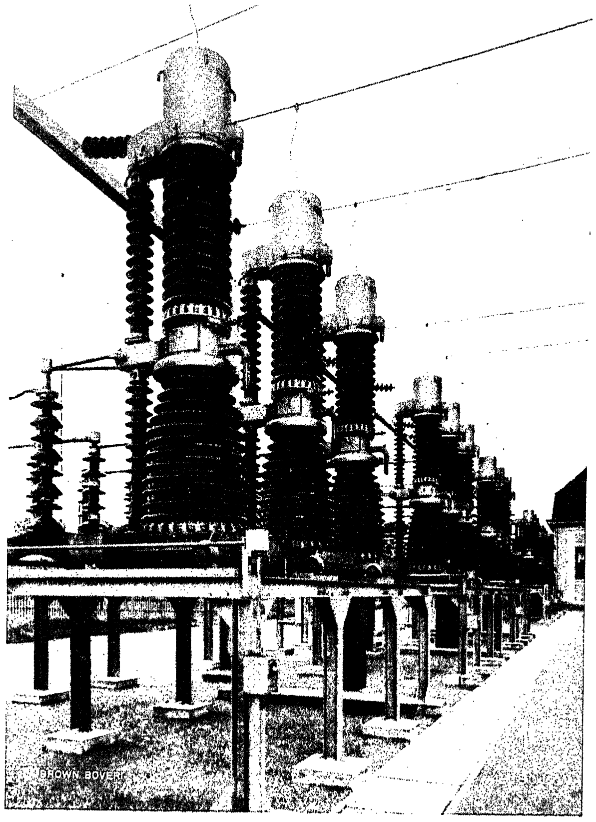

Fig. 9. — The six sets of convector circuit breakers 130 kV in the Chèvres substation.

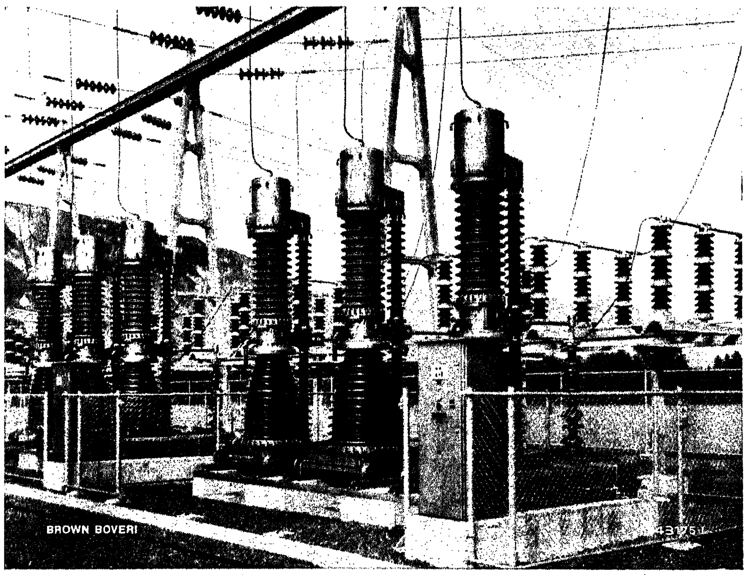

Fig. 10. — Two sets of three convector circuit breakers 130 kV, in the Saint-Triphon substation.

The Chèvres substation (Service de l'Electricité de Genève).—The engineers of the Service de l'Electricité de Genève showed their confidence in the new circuit breakers by putting six sets, Fig. 9, into their Chèvres substation. There are three sets on the high-voltage leads of the transformers and three on the incoming and outgoing lines. These breakers are mounted on frames which carry both breaker and disconnecting switch, an arrangement which meets local conditions. Here, there was already a big building standing so that certain problems relating to overhaulage of the apparatus did not come up.

Service results.—The system was put into practical operation in the spring of 1935. Since then, the circuit breakers have had to handle numerous cases of short circuits. To begin with, there were shorts of different kinds produced artificially to allow of making final adjustments and then some accidental ones, principally earths, caused by birds. Further the breakers had, frequently, to work under particularly difficult conditions during closing operations, but, chiefly, during the cutting out of lines under no load when a low current with maximum phase displacement had to be cut, without producing excess voltages. The circuit breakers gave excellent results in all these cases, coming fully up to expectations and confirming the results already attained in the manufacturer's testing plant. Overhaulage of the apparatus showed no signs of abnormal wear of the parts implicated, contacts in particular. Inspection of contacts is, in fact, a very easy matter in convector circuit breaker; it is not necessary to move the breaker, a drainage cock allows of emptying the few kilos of oil from the upper insulator and then the two contacts can be reached by two apertures, one on each side of the medium metallic part of breaker. Usually, these openings are masked by a rectangular plate, shown in the illustrations. There are four bolts to unscrew and, then, the complete fixed contact with the valve and its spring as well as the sparking ring can be removed. It is just as easy to take out the tip of the moving contact, and all the insulating rings of the convector proper.

From the dielectric point of view, these breakers showed no weak spot. Being generously dimensioned, they stood up well to excess voltage due to travelling surges. Further, their disconnecting switches protect them, when they are open, against internal and external flash-overs. Finally, the distribution of voltage along certain insulating driving organs, is regulated by means of suitable metal rings and this has proved a most efficient solution. The severe tests to which the breakers were put in the shops have been confirmed.

Thus, a year's service on the distribution system of western Switzerland has confirmed, once again the selective qualities and the precision of Brown Boveri distance relays, and this period of practical operation has shown that the convector circuit breaker possesses those qualities of rapid breaker operation and electrical and mechanical reliability demanded by modern plants.

(MS 987) *F. Werthmann. (Mo.)*

THE SLUICE-GATE PLANT OF THE KLINGNAU HYDRO-ELECTRIC POWER STATION.

Decimal index 621.34:627.82.

THE Klingnau hydro-electric power station on the river Aare has a sluice-gate plant conceived on new lines and which differs considerably from others of the same kind built in recent years. The following paragraphs give some data on the mechanical and electrical equipment of the plant in question.

The L. von Roll'sche Eisenwerke, Giesserei Bern, delivered the mechanical part of the equipment, and they also built the heavy-duty hoisting chains for the gates. The four sluice openings, 30 m wide, have, each, got two movable gates, an upper and a lower one (see illustration on cover of this number). Each of these gates is controlled by a separate winch gear, and their position can be adjusted independently of each other, so as to suit the momentary water conditions on the river. There are end-travel switches to limit the travel of the gates.

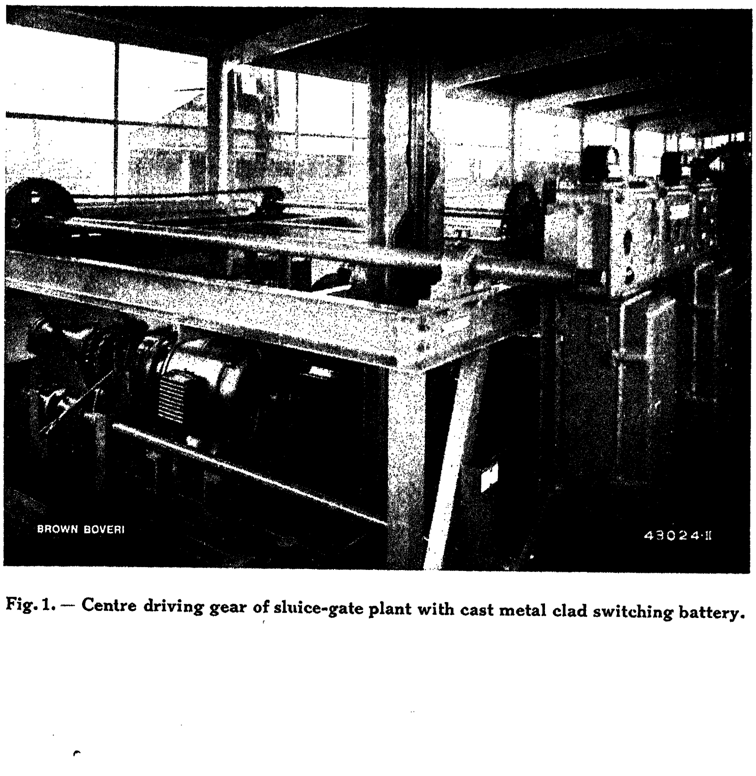

Fig. 1. — Centre driving gear of sluice-gate plant with cast metal clad switching battery.

Fig. 2 shows the layout of the drive located above one of the sluice openings. The two lateral driving gears with the chain-

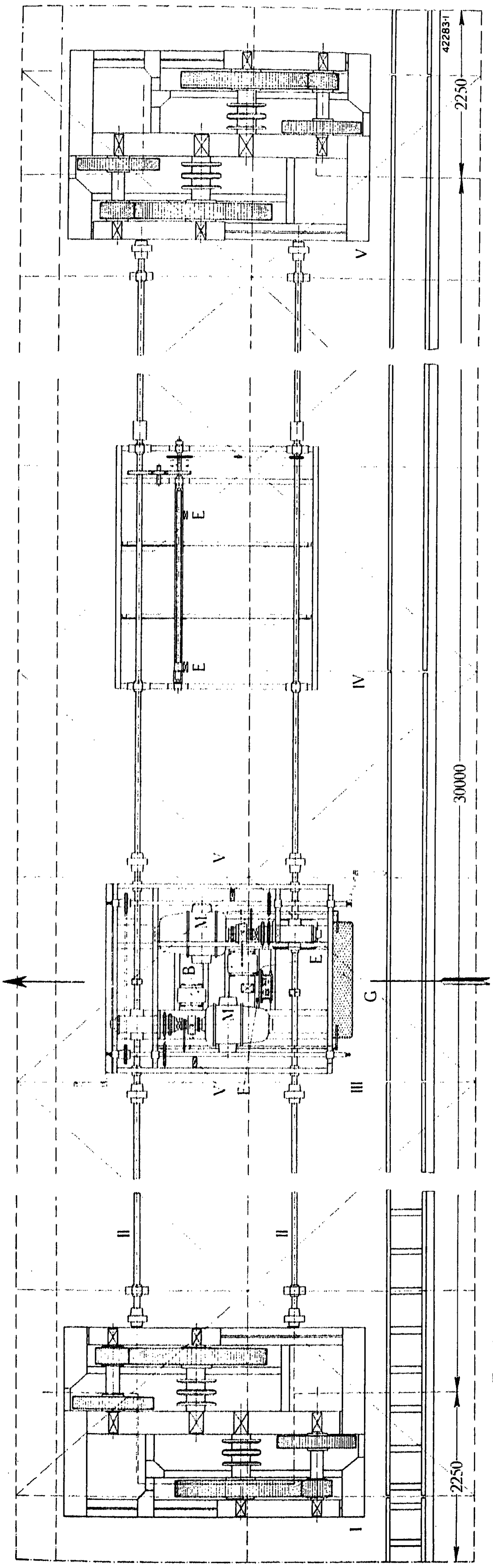

Fig. 2. — Klingnau hydro-electric power station on the river Aare. View of the winch gear, over one of the sluice-gate openings, seen from above.
B. Brake-releasing magnet. M. Motor. V. Interlocking switch, hand drive. I. Lateral driving gear. II. Transmission. III. Centre driving gear. IV. End travel switch mechanism, differential gear. V. Lateral driving gear.
E. End-travel switch. G. Cast iron clad switching battery.

drive drums and the first reduction gear are clearly shown. The winding gear and driving motors, the reduction gears and end switch mechanism are shown in the centre. Special chains of powerful type perform the hoisting and lowering duty. Chain guides and guards assure perfect winding in and paying out of the chain. When the gates are raised, the chains are stored away, automatically, in niches provided in the pillars. The reduction gears are of high-precision high-grade quality and give absolutely reliable service. The tractive effort of the winch gears, per sluice gate opening, is 180 t for the lower gate and 115 t for the upper one.

Each motor drives its reduction gear through a slip coupling. The latter protects the motor against the effects of peak loads and accidental overloads, as far as possible. The first high-speed reduction gear is of worm-wheel type of the latest design with a steel worm and bronze-rimmed worm wheel. It is carried in ball bearings and revolves in a closed casing, in an oil bath. A shoe brake, worked electromagnetically, stops the motor immediately, once the current has been switched off. This shoe brake is held closed by the force of a spring, and is raised by the counter-force of an electro-magnet, as long as the motor is under voltage. If voltage fails, the brake is applied automatically and stops the whole drive. In order to be able to move the gates, in an emergency, and if the current is cut off, there is an emergency drive installed. There are interlocks, so that the brakes are raised when the gates are being manually operated and, further, so that the current to the motor is cut off, in order to prevent accidents taking place, due to the motor being switched in, inadvertently.

There is a position indicator on the bridge which gives the momentary position of the two gates. This gives the exact amount by which the gates are raised, and their relative position. The hoisting speed of both gates, when motor-driven, is 0·3 m/min. Owing to the different loads and the consequent difference in the speed of the induction motors driving them, it is possible that the movement of one gate may slowly lead on the other. When this happens, in order to prevent the upper gate being superimposed on the lower one, or that both gates draw away from one another, entirely, an interlocking device has been introduced, actuated by a differential gear. When the admissible extreme position of the drives has been reached, this interlocking mechanism comes into action and the plant is brought to a standstill. Further, as said before, there are end-travel switches at the upper and lower end positions of each gate, to prevent the limit position being exceeded.

The electric equipment delivered by Brown Boveri, for three-phase current, 380 volts, 50 cycles,

comprises eight induction motors having a special design of squirrel-cage rotors giving a high starting torque with relatively low switching-in current. A high starting torque is essential to drives of this kind in order that the gates move quickly and reliably even under exceptional conditions, caused by ice, for example. The four upper gates are, each, driven by a motor designed to deliver 17 kW for 30 minutes; the lower gates are driven by motors delivering 20 kW for 30 minutes. These motors are spray-water proof and the windings are specially insulated against damp. There is a cast metal clad switching battery beside each winch set, which contains the motor protective devices in the lower part (Fig. 1) and push buttons above, to hoist, lower or stop the upper and lower gates. There are also lamps for signalling and controlling purposes. Thus, any of the gates can be actuated or stopped, simply by depressing a push button. Every push button of the switching battery has another one in parallel to it and which is located in the power station itself. The gates can, therefore, be operated from the bridge over the sluice openings and from the power station, which facilitates service. There is, of course, a corresponding signalling plant in the power station which shows which gates are being moved and which ones are immobile.

There are cast metal clad end-travel switches, the duty of which is to prevent the gates exceeding their extreme allowable position. If it occurs that a gate does exceed an end-travel position the drive sense can be immediately reversed and the proper conditions re-established. There is a low-voltage distribution plant with the requisite fuses and disconnecting switches, placed at the end of the sluice-gate bridge, next the power station. All lines from this low-voltage plant lead to the cast metal clad switching batteries, and to the motors. From this plant the lines also take off to the control circuits for light and for heating.

The plant is completed by a float control, which lowers the upper gates automatically if the level of the water above the station gets too high.

The whole plant has been in service for over a year and the gates and the entire electrical equipment have given complete satisfaction.

(MS 992) *E. Altschul. (Mo.)*

A TESTING APPARATUS FOR TRANSFORMER AND CIRCUIT-BREAKER OILS.

Decimal index 621. 315. 615. 2. 0014.

I. GENERAL REMARKS.

In order to be able to determine the dielectric strength of insulating oils and also of solid insulating materials, Brown Boveri developed a testing apparatus which allows of attaining a testing voltage of 70,000 V. A maximum testing voltage of this magnitude was chosen because, in testing the high-grade oils available to-day, with electrodes five millimetres apart, a break-down voltage of as high as 70 kV can be reckoned with. The ordinary tests carried out with testing apparatus built for lower maximum voltage and smaller spark gaps, followed by adjustment calculations to one centimetre between electrodes has been proved unreliable in practice. This is because the conversion factors take the field gradients into account but do not reckon with the flow of oil and the presence of impurities which must always be expected. If tests are always carried out with five millimetres between electrodes reliable comparison figures are obtained.

Further, in order to allow of making voltage tests with this apparatus on objects such as transformers, cables, etc., the testing transformer is dimensioned for a continuous rating of 2 kVA at a maximum testing voltage of 70 kV.

II. TESTING TRANSFORMER.

The testing transformer is designed in the following manner:—Each leg of a two-legged core is fitted with an insulating container made of hard paper (Fig. 1). The high and low-voltage winding are lodged in the interior of this cylindrical-shaped container the whole being filled with an insulating compound so that the windings are completely embedded in the insulating mass. The bottom ends of both the high-voltage windings are connected together and earthed through the transformer core (middle-point of high-voltage winding earthed in this way). The top ends of the two high-voltage windings are, each, connected to a terminal bushing which makes a tight fitting in the insulating wall. The beginning and end of both low-voltage coils are carried to a terminal board secured to the upper yoke so they can be changed over for connecting in series or in parallel, for 220 V or for 110 V, for example.

III. OIL-TESTING RECEPTACLE.

Both terminals of the high-voltage winding are led to two metal carriers which are supported on porcelain insulators. These carriers are forked-shaped at the top and serve to hold the oil-testing receptacle

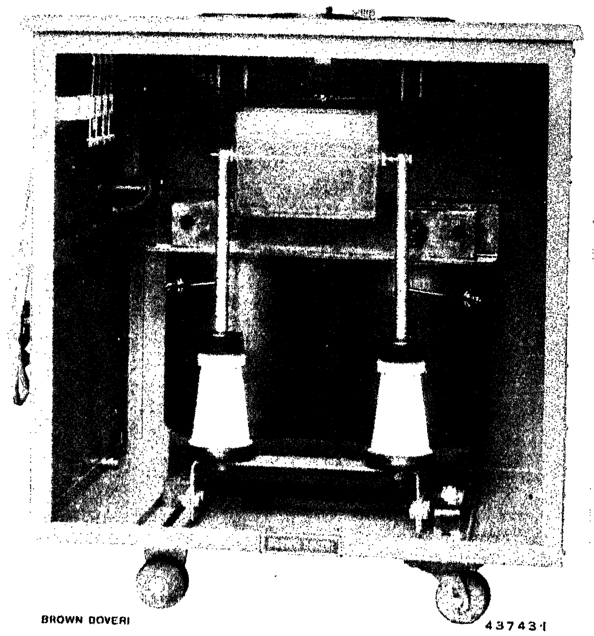

Fig. 1. — Interior view of oil-testing apparatus for 70 kV, with rear wall of casing removed.

(Fig. 1). The latter consists of a rectangular glass tank with built-in horizontal electrode holders one of which is fixed and the other movable. The electrodes are brass spheres of 12·5 mm diameter, according to the rules of the Swiss Electrotechnical Association (S.E.V.). The spark gap between electrodes, 5 millimetres, as laid down by the above Association, is exactly set by means of a calibrated gauge five millimetres thick. The glass tank is so dimensioned that no flash-over from electrode to electrode can take place along its outer surface, at the maximum testing voltage attainable. About 1·4 litres of oil must be poured into the tank in order that the electrodes be sufficiently immersed. This amount of oil is only required, however, with oil having great dielectric strength. For oil of considerably lower dielectric strength a smaller glass tank can be used, so that about half a litre of oil suffices.

IV. CONNECTIONS.

The connections are made according to Fig. 2. The supply current is brought in from the system through a flexible rubber-insulated cable (Fig. 3). At the point where the cable is led into the apparatus proper there is a two-pole over-current automat, which can also be closed and opened by hand. It breaks the circuit of the low-voltage winding whenever there is a flash-over between the electrode spheres in the glass tank, this independently of the voltage at which the flash-over takes place.

The testing voltage is regulated on the low-voltage side by means of a sliding resistance connected so as to act as a voltage divider. Voltage increase is gradual as the section of the wire of the sliding resistance is dimensioned for the increasing excitation current in the low-voltage winding. There is an ohmic resistance of constant value placed in series with the sliding resistance and the duty of which is to limit the supply current to an admissible value when a flash-over in the tank takes place.

The voltmeter connected to the low-voltage winding of the testing transformer has two scales, for 16 and 80 kV and indicates the magnitude of the test voltage. A voltmeter change-over switch allows of passing from one measuring range to the other.

Further, an ammeter inserted in the current leads to the low-voltage winding allows—after taking the ratio of the transformer into account—of measuring the current taken by whatever object may be under test.

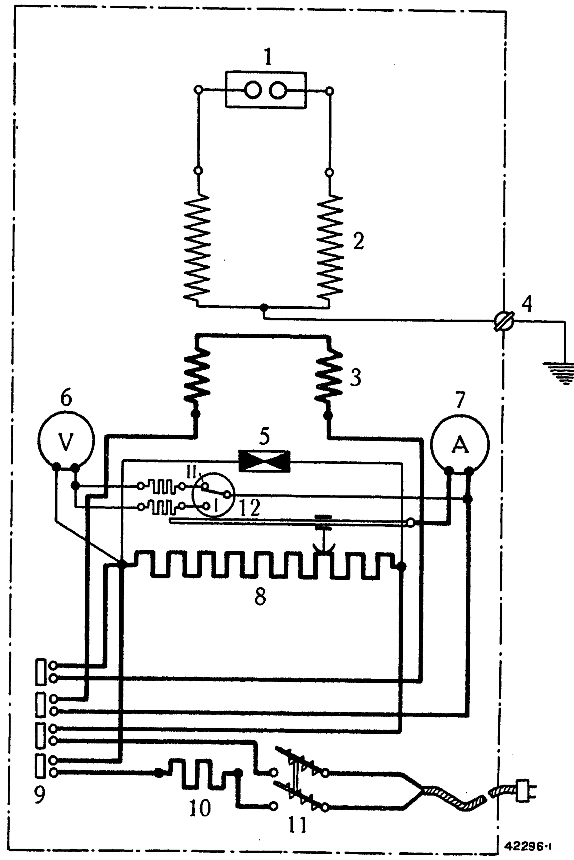

Fig. 2. — Diagram of connections of oil-testing apparatus.

1. Oil-testing glass tank.
2. High-voltage winding.
3. Low-voltage winding.
4. Earthing screw.
5. Signal lamp.
6. Voltmeter.
7. Ammeter.
8. Sliding resistance.
9. Cutting-out contact.
10. Resistance.
11. Over-current automat.
12. Voltmeter change-over switch.

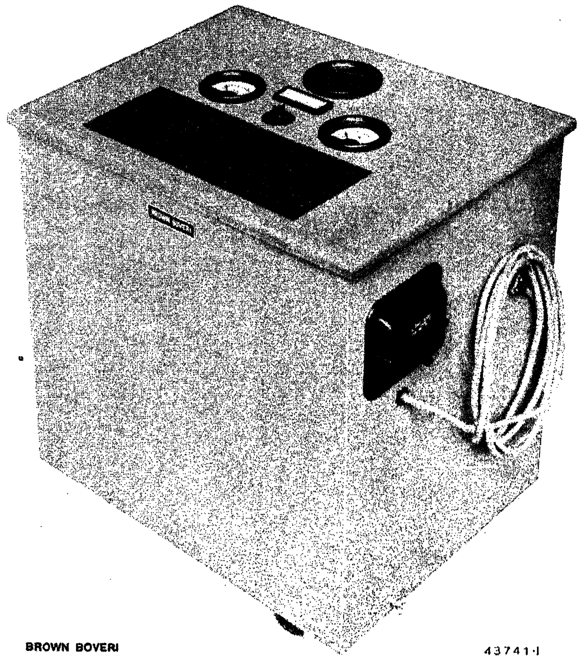

Fig. 3. — Oil-testing apparatus for 70 kV.

The lighting up of the signal lamp lodged in the cover of the testing apparatus shows that the testing transformer is under voltage. Further an observation glass pane let into the cover over the glass oil-testing tank allows of supervising the electrodes in the tank, during the test and without any danger.

The cover can be raised and maintained so by a support, to allow of fitting in the oil-testing glass tank (Fig. 4).

In order that the operator carrying out the above operation should not be endangered by high-voltage, the connections are so made that when the cover is opened the current to the testing transformer is interrupted.

V. EARTHING.

An earthing screw lodged on the lower part of the casing of the testing apparatus, on the lever-switch side allows of earthing the testing apparatus. The middle point of the high-voltage winding of the testing transformer and the active iron core of the transformer are connected, in the inside of the casing, to this earthing screw. Care must, therefore, be taken, before connecting the testing apparatus to the supply system, that the said casing of the testing apparatus has a proper conductive connection to earth.

In voltage tests in which one pole has to be earthed, the testing voltage can be taken between one of the high-voltage terminals and the earthing screw.

In this kind of insulating test the maximum testing voltage attainable is 35 kV.

VI. POWER CONSUMPTION.

The testing transformer is designed for a continuous load of 2000 VA. The wattless power input under full excitation is about 30 % of the full-load input, so that, for oil testing, the apparatus can be connected to any lighting system.

The short circuit impedance of the testing transformer and the series resistance are so calculated that, when breakdowns take place in tests made on objects, the resulting current surges have no deleterious effects on the supply system.

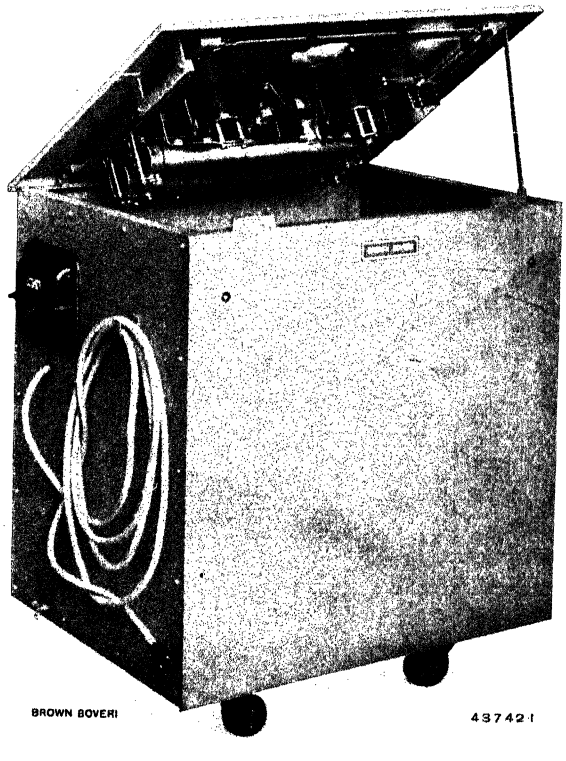

Fig. 4. — Oil-testing apparatus for 70 kV with cover of casing raised.

VII. MECHANICAL DESIGN.

The housing is composed of an angle-iron framework covered with metal sheeting of 1 1/2 millimetres thickness.

In order to make voltage tests on objects which must be tested outside the apparatus, the back partition of the housing can be removed to allow of leading out the testing voltage.

The testing apparatus mounted on four stout rollers, of which two are swivelled, can easily be moved in any direction

The total weight of the testing apparatus ready for service is only about 180 kg.

(MS 995) *A. Neuenschwander. (Mo.)*

THE 410-H. P. DIESEL-ELECTRIC MOTOR COACHES OF THE MADRID-SARAGOSSA-ALICANTE RAILWAY (M. Z. A.)

Decimal index 621. 335. 4. 033. 44 (46).

In the period from September 1935 to February 1936, the Madrid-Saragossa-Alicante (M. Z. A.) Railway put into service four 410-H. P. Diesel-electric coaches, which had been ordered at the beginning of the year 1934. To complete the information which appeared in this Review[1], giving the chief data and service conditions specified when these vehicles were designed, some more detailed information on the design and on some important features and innovations introduced to the electrical equipment are given in the following paragraphs.

The coachwork was carried out by the *Compañia Auxiliar de Ferrocarriles, Beasain* (Spain) who were the general contractors for the complete coaches. *Maybach-Motorenbau Friedrichshafen* delivered the Diesel-engine plant and *Brown Boveri, Baden*, the electrical equipment. Fig. 1 shows the general design of the motor coaches and the layout of the Diesel-electric equipment. The main data is tabulated below.

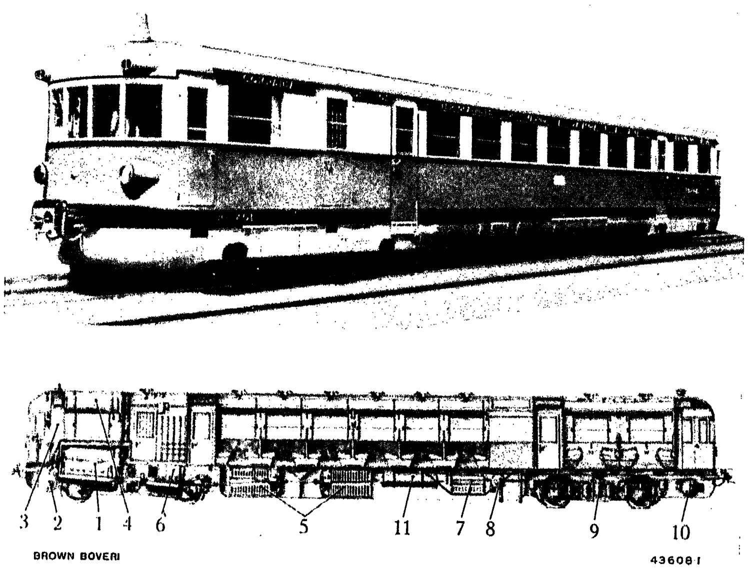

Fig. 1. 410-H. P. Diesel-electric motor coach of the Spanish M. Z. A. Railway.

1. Diesel engine.
2. Noise deadener.
3. Exhaust pipe.
4. Fuel container.
5. Cooling plant for the Diesel engine.
6. Generator set.
7. Storage battery.
8. Motor-compressor set.
9. Bogie holding the driving engine.
10. Heating boiler, oil fired.
11. Container for compressed air for brake.

Coachwork.—Light steel work according to a design by the Waggonfabrik Uerdingen; stream-line design of coach.

Serial number of motor coaches	WE 401—404
Gauge	1674 mm
Axle arrangement	2—2 A two 2-axle bogies
Diameter of driving and carrying wheels	920 mm
Wheel base:—	
engine bogie	3500 mm
driving-motor bogie	2700 mm
Span between bogie pivots	15,000 mm
Length of coach	22,225 mm
Maximum width of coach	2920 mm
Number of passengers, seated, IInd class	16
Number of passengers, seated, IIIrd class	64
Floor area of luggage compartment	5·8 m²

Automatic compressed-air brake of the Knorr type, working on brake drums.

Oil-pressure hand-operated brake.

Automatic central coupling of the Scharfenberg type.

Heating by oil-fired totally-automatic heating boiler of the Pintsch type.

Diesel-engine plant.

Design of Diesel engine:— 12-cylinder, 4-cycle engine with two V-placed rows of 6 cylinders each, with straight fuel injection.

Continuous output at an altitude of 400 m above sea level and with air at 20° C	410 H. P. at 1400 r. p. m.
Cylinder bore	150 mm
Piston stroke	200 mm
Weight of engine without water or lubricating oil	2127 kg
Water filling	about 95 kg
Lubricating-oil filling	about 45 kg

Cooler suspended on lower coach frame.

Three fuel tanks each of 330 l capacity.

Electric equipment.

Main generator Type G 620/6

One-hour rating	258 kW, 338 V, 680 A
Maximum voltage	700 V
Corresponding speed	1400 r. p. m.

Auxiliary generator Type G 340/6

Continuous rating	12 kW, 120 V, 1000—1400 r. p. m.

[1] See The Brown Boveri Review, No. 10, Oct., 1934, page 185:—"410-H. P. Diesel-electric motor coaches for the Madrid-Saragossa-Alicante Railway".

Two driving motors Type GDTM 2374
one-hour rating . . each 160 H. P. (380 V, 340 A) at 960 r. p. m.
Maximum operating speed . . . . 2200 r. p. m.
Reduction-gear ratio 1 : 3·58

Starting battery of "Tudor" make . . 90 cadmium-nickel cells of 155 Ah capacity with a 5-hour discharge.

Brown Boveri motor-compressor set Type GZB 3 for an air intake of 700 l/min at a counter-pressure of 6 kg/cm² gauge.

Automatic regulation of separate excitation of the main generator to constant Diesel-engine output, by servo field-regulator. Safety control.

Tractive-effort and speed conditions.

Tractive effort at wheel tread referred to Diesel-engine output of 410 H. P.
Maximum value . . . 4100 kg from 0 to 15 km/h
At one-hour rating . 1810 kg at 46·2 km/h
At continuous rating . 1240 kg at 69·5 km/h
830 kg at 100 km/h

Highest travelling speed . 100 km/h

Weights.

Coach alone . . . . 29,100 kg
Diesel-engine plant . . 3800 kg
Electrical equipment . . 8600 kg
Tare . . . . 41,500 kg
Driving stores carried (fuel, lubricating-oil, cooling water and consumed water) . . . . . . 1500 kg
Weight ready for service (without passengers or luggage) . . . . . 43,000 kg
Load carried (passengers and luggage) . 9200 kg
Weight ready for service and with full complement of passengers and luggage . 52,200 kg
Adhesion weight with full complement of passengers and luggage . . . . 25,350 kg

The Diesel-engine and the main and auxiliary-generator set are mounted on separate welded auxiliary frames which are carried in the frame-work of the bogie being supported at three points, on rubber shock-deadeners. The main and the auxiliary generator form a two-bearing set of great compactness which is a patented design (Fig. 2). The driving motors are self-cooled series-wound motors of axle-bearing design, with geared drive on one side, the big gear wheels being spring-cradled. Part of the apparatus and auxiliary machinery (change-over switch, storage battery, motor-compressor set, auxiliary set for battery charging) is lodged under the coach floor or in the lower part of the coach. The rest of the apparatus is placed in a cubicle in the luggage compartment and in the driver's cabs.

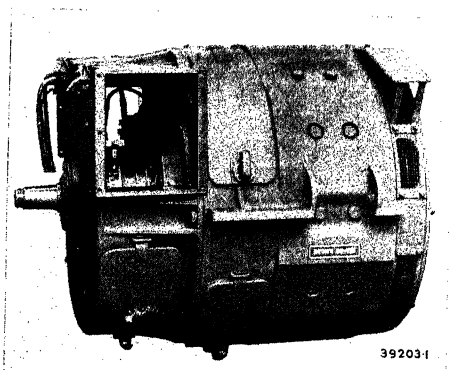

Fig. 2. — Main and auxiliary generator set of specially compact design.

The fundamental connections of the electrical

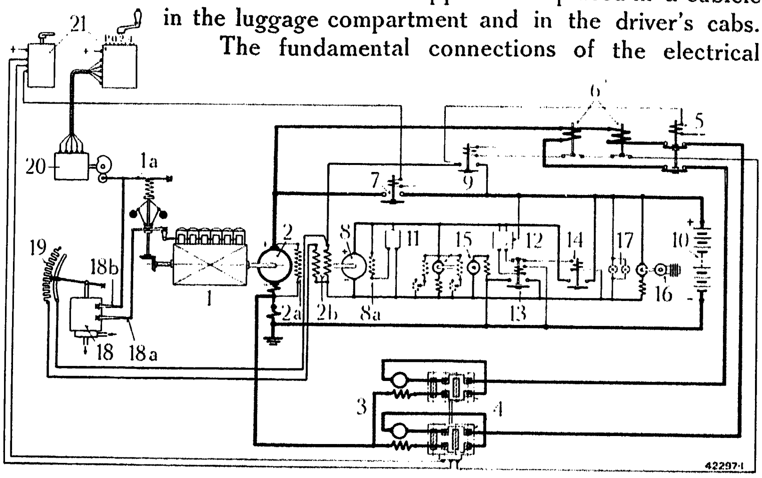

Fig. 3. — Simplified diagram of connections of the motor coach.

1. Diesel engine.
1a. Speed adjuster for Diesel engine.
2. Main generator.
2a. Auto-excited shunt winding.
2b. Separate-excitation shunt winding.
3. Driving motors.
4. Change-over switch.
5. Motor-cut out contactor.
6. Over-current relay.
7. Starting contactor.
8. Auxiliary generator.
8a. Auto-excited shunt winding.
9. Excitation contactor.
10. Storage battery.
11. Voltage regulator.
12. Voltage and reverse-current relay.
13. Battery contactor.
14. Auxiliary-generator contactor.
15. Auxiliary set for battery charging.
16. Motor-compressor set.
17. Lighting-current circuit.
18. Servo field-regulator.
18a. Connecting lever between the fuel regulating rod and the regulating valve of the servo-motor.
18b. Torque-setting device on the servo field-regulator.
19. Regulating resistance.
20. Speed adjuster.
21. Controller.

equipment are shown in Fig. 3. The motor coaches are equipped with Brown Boveri servo field-regulator control[1]. For the various Diesel-engine standard speeds the following outputs are available on the electric power transmission, which outputs correspond to five travelling steps on the master controller.

Controller step	r. p. m.	Output in H. P.	Notes
0	885	0	No-load
1	1000	80	Load caused by main and auxiliary generator as well as mechanically-driven cooling fan.
2	1090	140	
3	1210	200	
4	1290	330	
5	1400	410	

The average output to the auxiliary drive attains 19 H. P. The output setting of the Diesel engine is carried out by means of an electro-pneumatic speed (r. p. m.) adjuster: as the r. p. m. rise the torque is

[1] See The Brown Boveri Review, year 1935, p. 239.

increased simultaneously (change in the tension of the spring of the centrifugal regulator and of the closing setting of the regulating valve of the servo field-regulator). Fig. 4 shows the working curve of the main generator under the influence of the servo field-regulator for the five driving steps and a regulating range in the separate excitation corresponding to maximum excitation at 1400 r. p. m. and minimum excitation at 1000 r. p. m.

The control is designed either for multi-control of two motor coaches coupled together or else of two train units coupled together and each composed of a driving coach and of a pilot coach. The pilot-current couplings are mounted on the automatic coach

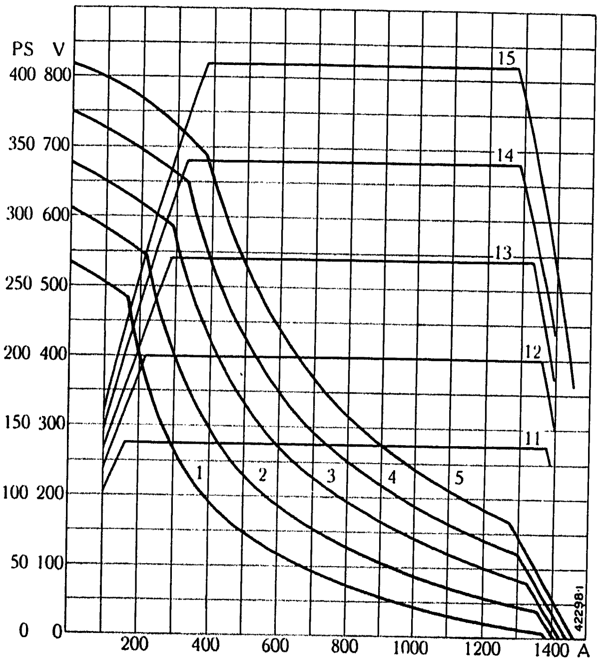

Fig. 4. — **Working curves of the main generator under the influence of the servo field-regulator.**

1—5. Regulated generator voltage in function of the current, at 1000, 1090, 1210, 1290 and 1400 r. p. m. and regulating range in the separate excitation corresponding to maximum excitation at 1400 r. p. m. and minimum excitation at 1000 r. p. m.

11—15. Power output of the Diesel engine in function of the strength of the generator current at 1000, 1090, 1210, 1290 and 1400 r. p. m.

couplings. Apart from the speedometers and cooling-water temperature indicators for the Diesel engines of two motor coaches under multi-control, there is a main-generator voltmeter and ammeter, designed as a cross-indicating instrument, on each driver's desk, which also serves to estimate the Diesel-engine load. When the point of intersection of the two needles coincides with the cross curves which carry the figures 1000—1400, this means that the Diesel engine is fully loaded for the speed in question. An upward displacement of the point of intersection of the two needles means an overload on the Diesel while a displacement downwards means that the Diesel engine is not fully loaded.

To cope with the relatively big amount of power required by a motor coach with a pilot coach coupled to it, for lighting, the following arrangement has been used for supplying the auxiliary service, which is employed, here, for the first time in Diesel-electric vehicles. The auxiliary generator is designed for a terminal voltage of 120 V, corresponding to a battery-discharged voltage of 120—110 V, and this generator voltage is maintained constant at all speeds between 1000 and 1400 r. p. m., by means of a quick-acting voltage regulator. The auxiliary services, control-current circuits and lighting system are direct-connected to the terminals of the auxiliary generator, when the Diesel-generator set is running (incandescent lamps for 120 V rated voltage). There is an additional set to charge the battery (booster) which produces a voltage of 0—50 V and by which amount the constant voltage of the auxiliary generator can be raised. This additional set comprises a D. C. compound motor, forming a two-bearing set with a D. C. generator separately excited and counter-compound wound. Fig. 5 shows the working curve of this set. By speed variation of the driving motor (adjustable resistance in the auto-excitation or change in the separate excitation of the booster—adjustable excitation resistance) any charging voltage curve can be attained.

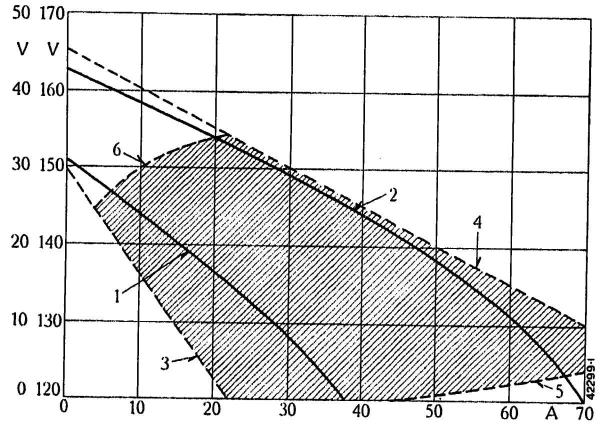

Fig. 5. — **Working curves of additional set for battery charging.**
Ordinates:— Voltage of battery respectively additional voltage of booster.
Abscissae:— Charging current.
1. Voltage in function of current at rated loading.
2. Voltage in function of current at forced loading.
3. Voltage curve at lowest loading.
4. Voltage curve at maximum loading.
5. Load voltage in function of load current, the battery being completely discharged.
6. Load voltage in function of load current, the battery being completely charged.

Service results.—A number of trial runs were carried out with the first of the four motor coaches, immediately it was completed. These runs were made from Beasain (20th—30th Aug., 35), and revealed not the slightest defects and were most satisfactory. On the 3rd of Oct., 1935 motor coach WE 401 ran from Beasain to Madrid (about 670 km); on the 6th of Sept. the official taking-over tests took place on the approx. 200 km long Madrid-Cuenca line section; the results thereof are given in the table on page 228.

Afterwards, a series of most satisfactory official-demonstration runs were carried out with motor coach WE 401 among which:— on 4th Oct., 35 a trip Madrid-Sevilla, 571 km, the whole line section being covered without a halt, on the outward journey, in seven hours, twenty minutes and, on the return journey in eight

Motor coach WE 401 weight for service at the taking-over tests = 46·5 t	Laid down in specification	Attained during the test runs
Run Madrid-Cuenca	2 h 29 min	2 h 9 min
Start on the level at 800 m alt. from 0 to 100 km/h	150 s	115 s
Maximum speed		
on the level	100 km/h	116 km/h
on 17 ‰ gradient	70 km/h	85 km/h
Fuel consumption for the total run, going and coming	12 g/tkm	10 g/tkm

hours, under strict observance of the time schedule laid down. On the 10th Oct., 35, a trip Madrid-Barcelona, 684 km, travelling time nine hours and 17 minutes.

With the three other motor coaches delivered, the taking-over runs were performed without revealing any trouble. The trial runs with two motor coaches in multi-control connection and one motor coach with a pilot coach were also most satisfactory.

These motor coaches specified for a maximum speed of 100 km/h actually attained, under test and on the level, 145 km/h. The individual coaches covered up to 1380 km in a day.

The behaviour of the Diesel and electric plants was irreproachable. Starting is rapid and devoid of shocks, running is smooth; there are no vibrations perceptible, in the coaches, due to the Diesel engine.

(MS 996) *A. E. Muller. (Mo.)*

NOTES.

Hinged switch panels for mounting on partitions in pumping stations.

Decimal index 621.316.34.

THERE is, generally, very little space available in pumping stations, so that the requisite switchgear must be as compact as possible. In small stations this switchgear is, usually, mounted on a wall-type panel. On the other hand, switchgear plants of this kind have to satisfy very severe regulations, which are fully justified by the fact that the apparatus is generally lodged in more or less damp rooms.

The Swiss regulations governing indoor electric plants, their design, service conditions and upkeep, stipulate, in paragraphs 31-37, conditions to be fulfilled which lead to an excellent layout of the wiring, make supervision easy and apparatus and lines very accessible.

Fig. 1 shows a wall type of board for a small pump-station. Control is, here, for automatic service and works so that the pump set is switched in by a time switch. Switching out can be effected in two ways:— either by the same time switch or by a minimum-power relay. If the delivery pipe of a centrifugal pump is shut off, the power input of the driving motor falls abruptly. This drop in power input can be used to cause the pump set to be cut out, by having it influenced by the minimum-power relay. The fall of the volume of water delivered is attained by means of a float valve which separates the delivery pipe from the reservoir as soon as the latter is full. The utilisation of this simple method, requiring no electric connecting wires between reservoir and pumping station, is limited of course, to those cases in which the closing of the delivery pipe at the reservoir itself really causes the water delivery of the pump to fall abruptly. Thus, it is necessary to ascertain whether, despite the filled reservoir and closed pressure pipe, there is not so much water being pumped (for running fountains, etc.) that there is no essential drop in the power intake of the pump.

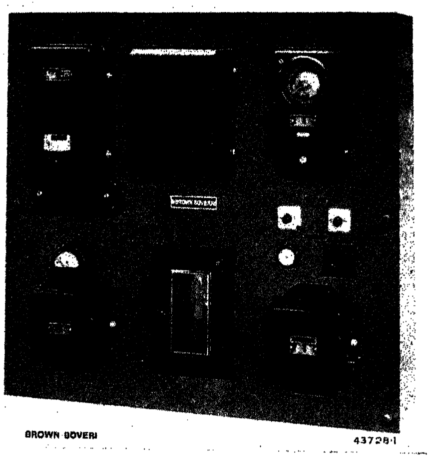

Fig. 1. — Hinged switch panel for mounting on partitions in pumping stations.

The switchboard shown in the illustration contains the apparatus necessary for service of this kind, namely:— an ordinary tarif meter, the motor switchbox with built-on ammeter and thermal release, the time switch with its main contactor for switching in and out the motor, the minimum

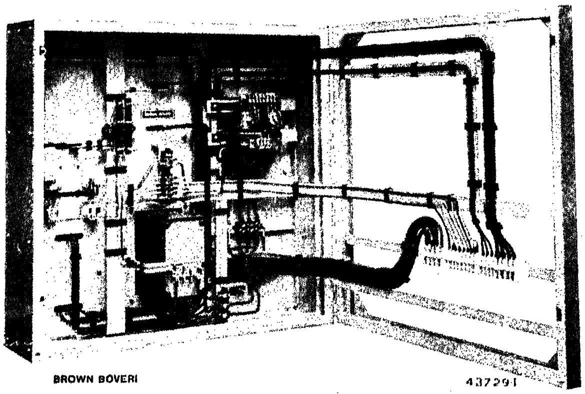

Fig. 2. — View of panel, swung out.

power relay for cutting-out the motor, an emergency switch allowing of starting up the motor at any time even when there is trouble on the automatic apparatus, a lighting connection for 36 V, 50 cycles, connected to a small transformer.

The connections are so made that during the running hours set for, automatic reclosings of the switch take place, from time to time; it is, thus, possible to arrange that, at the time the high tariff comes into operation, the reservoir is always full.

A wall panel like that of Fig. 1 is, of course, only relatively accessible from the rear, this although the closing metal sheet can be removed after loosening some screws. For this reason, Brown Boveri delivers, to-day, switchboard panels which can be swung out while leaving untouched the incoming and outgoing leads. Fig. 2 shows one of these panels, open. On the right, is seen the frame of angle iron which is secured to the wall. The incoming leads to the hinged part are through flexible cables. Great care was devoted to making the conductors easy to supervise. The different circuits are characterized by different colours while maintaining adequate spacing between lines laid in parallel or crossed. A panel of this type should be the last word in safety in stations of the type in question, here.

(MS 999) *U. Vetsch. (Mo.)*

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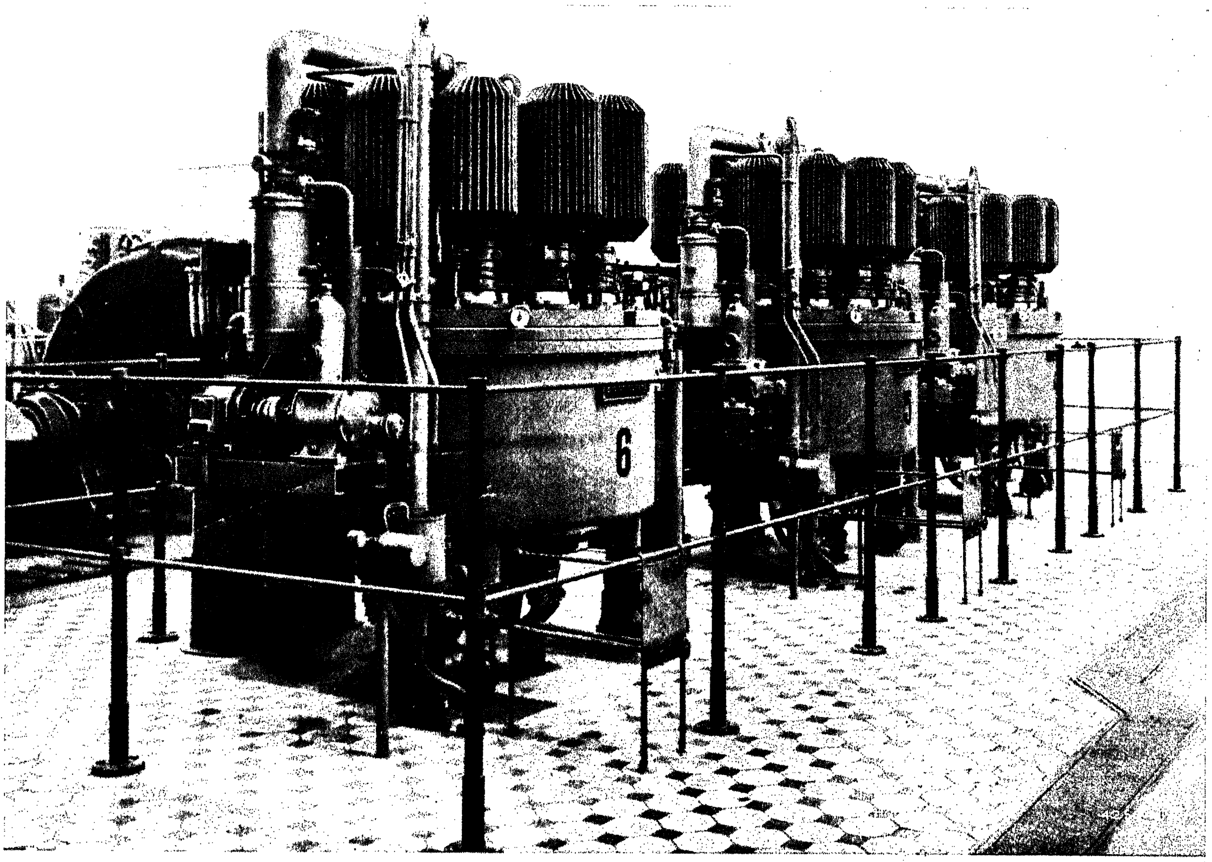

MUTATOR PLANT FOR AN ALUMINIUM WORKS.
Three sets each of three mutators, aggregating 40,500 A, electrolytic voltage 660 V, 26,500 kW.

CONTENTS:—

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIII OCTOBER, 1936 No. 10

COMPENSATION OF HIGHER HARMONICS IN THE EARTH CURRENT IN UNDERGROUND OR MIXED HIGH-VOLTAGE DISTRIBUTION SYSTEMS.

Decimal index 621. 316. 935.

I. INTRODUCTION.

UP till to-day, earth-current harmonics in most overhead systems and, even, in cable systems, of average extent and voltage, have not been strong enough to be a cause of trouble. However, it can be foreseen that these harmonics will attain considerable magnitude, in the future, owing to the increasing linking up of big distribution systems. Even to-day, they reach considerable values in very high-voltage systems especially in those comprising a big proportion of cables and it is, sometimes, necessary to compensate them in order that the earth arcs may be extinguished.

It will suffice to give, as an example, the case of an underground system, an analysis of the voltage oscillograms of which revealed, among others, the presence of a fifth harmonic in the voltage curve, the amplitude of which attained 4·5% of the fundamental wave. The neutral of the system being insulated, the voltage of two sound phases to earth, in the case of an earth fault on the third phase, attains the value of the line voltage, as is known. Thus, each of the sound phases causes a capacity current to flow to earth, at the fundamental wave frequency, equal to $E\sqrt{3} \times \omega \times C$, where $E\sqrt{3}$ is the line voltage, ω the fundamental frequency multiplied by 2π and C the capacity of a phase to earth. On this current is superimposed the current due to the aforesaid fifth voltage harmonic, which is equal to $0{\cdot}045\, E\sqrt{3} \times 5 \times \omega \times C$, therefore equal to 22·5% of the fundamental earth current. The latter being about 200 A in the cable system under consideration, the current due to harmonic 5 attains 45 A. Now the inductive current of frequency 5 f supplied by the usual devices used to compensate the fundamental current is of insignificant magnitude. It is, therefore, important that the fifth harmonic should be compensated, in this case, by some special device, so as to allow of extinguishing the arc.

II. THE ORIGIN OF VARIOUS HARMONICS.— THEIR DISCRIMINATION.

The most frequent harmonics to be observed in the voltage oscillograms of a system are:—

(a) the third and multiples thereof, caused by the pole wheel (shape of the poles in machines with salient poles, distribution of the excitation flux in cylindrical rotors) or else caused by the magnetization of the transformers or by single-phase loading of the system;

(b) the fifth, seventh, eleventh, thirteenth, also caused by the poles or by the pole-wheels of the machines, or by the way the conductors are distributed in the stator;

(c) the harmonics of the 20 th order and above due to the pulsations in the teeth, the frequency of which depends on the number of teeth and the speed of rotation.

The voltage harmonics of the 3 rd order or multiples of 3 which are in phase with each other, that is to say have the same magnitude and direction at the same moment in all three conductors and the instantaneous sum of which, therefore, is not zero at every moment, but is a sine curve of triple magnitude, must be distinguished from the others among the harmonics which, like the fundamental wave, have a reciprocal displacement and the instantaneous sum of which is zero at all moments.

Further, the third harmonic proper must not be confused with the system of star voltages of triple frequency caused by a single-phase load on the system (a particular and most frequent example of which is produced by an accidental earthing of one phase) and the three vectors of which are displaced reciprocally by 120°, as is the case of all the other harmonics and of the fundamental wave.

In the following paragraphs, the third harmonic system in phase coincidence will be designated by the term *third harmonic* and that not in phase by *star system of triple frequency*. The currents of the latter follow the same track as the current of fundamental frequency or those of the harmonics of another order than 3.

The formation of this system of voltages of triple frequency is explained, as follows:—

As is known, a single-phase load branched between two phases of a three-phase system can be decomposed into two systems formed of symmetrical three-phase currents with successively opposed phases, the system termed "direct" and that termed "inverse". The field of the stator due to the inverse system rotates in counter sense to that of the rotor, inducing in it currents of double frequency (2 f). All takes

place, as far as the stator is concerned, as though the rotor were excited with current at a frequency 2 f; in other words, in the three phases of the stator a system of voltages, of frequency 3 f, is obtained. These voltages cannot be in phase in the three conductors as they are induced by the rotor.

Fairly frequently, in networks with asymmetrical loads, the existence of a voltage of frequency 3 f is detected in the oscillograms of composed voltages, in which it should, obviously, not appear if it was created by a harmonic in phase in the three conductors.

It should be added that this system of a frequency 3 f is eliminated, at least to a greater degree, in networks the alternators of which have a damping winding, as the latter chokes back into the air gap the inverse field of the stator.

There are various ways of discriminating between the two systems of frequency 3 f:—

The star system of triple frequency appears in the line voltage of the distribution system. The third harmonic, on the contrary, does not appear (because the three voltages being in phase, the voltage difference between two phases is zero). Thus, by analyzing an oscillogram of the line voltages of a distribution system it is possible to determine the magnitude of the star system of triple frequency.

Further, if the neutral is insulated, it suffices to oscillograph the earth current. The current of frequency 3 f, which the oscillogram will reveal, belongs exclusively to the star system of triple frequency, as will be shown further on.

As to the third harmonic, it can be obtained either by oscillographing the voltage at the terminals of the earthing coil on the neutral (this because, as will be explained, the third harmonics of the current in the three phases circulate through it and cause a voltage difference $= 3 \times J_3 \times 3 \times (\omega) \times L = 9 \times J_3 \times (\omega) \times L$), or else by deducing it from a comparative analysis of the composed voltage and the simple voltage, the latter containing a superimposition of the star system of triple frequency and of the third harmonic.

If the neutral is insulated, the third harmonic of the current cannot form.

Let us now consider the track followed by the various harmonics both with sound networks and with unsound ones caused by an earth fault and let us determine the methods of compensation which can be deduced therefrom.

III. CIRCUITS FOLLOWED BY THE CURRENT HARMONICS.

A. *The harmonics of the capacitive earth current under sound conditions.*

As a result of the preceding paragraphs, it can be stated that:—

1. The third harmonic and multiples thereof circulate in parallel through the three phases of the three-phase network, through their capacity to earth, through the earth and the connection of the neutral (see Fig. 1 or corresponding diagram of Fig. 2). Therefore, these currents can only be formed if there is a connection between the neutral point and the earth, which may be a direct one, or through a resistance or else through an extinguishing coil. If the neutral point is insulated, the third harmonic and multiples thereof does not appear in the capacitive earth current.

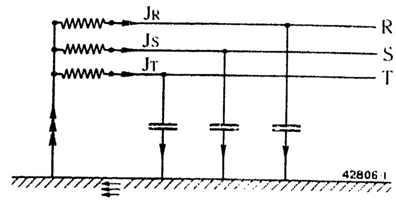

Fig. 1. — Formations of the third harmonic of the earth current in a network having the neutral point straight connected to earth; under sound conditions.

R, S, T. Three-phase network.
J_R, J_S, J_T. Third current harmonic in the three phases.

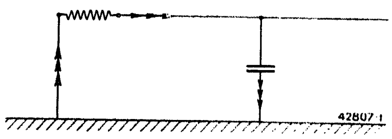

Fig. 2. Equivalent diagram to that of Fig. 3.

2. On the other hand, the current of the other harmonics as well as that of the star system of triple frequency can form whether the neutral point is connected to earth or not; its circuit closes, exactly like that of the fundamental current wave, through the capacities to earth, which form a star system (Fig. 3).

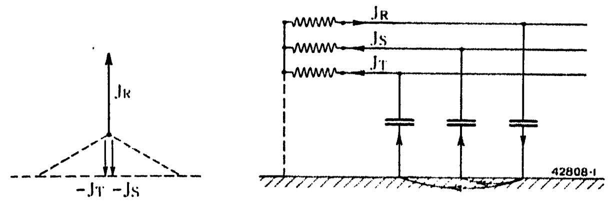

Fig. 3. — Formation of the harmonic of the earth current of the nth order other than 3, or of the star system of triple frequency, in a network with neutral point insulated or connected to earth; under sound conditions.

J_R, J_S, J_T. Instantaneous values of the current harmonics of the nth order, in the three phases.

B. *The harmonics of the capacitive earth current under unsound conditions (earth fault).*

a) *The neutral of the network is insulated.* The third harmonic cannot form. It cannot form a closed circuit through the faulty phase, because, in the circuit in question, the E. M. F. due to the third harmonic in that phase is equal and opposed to the E. M. F. of each of the other phases (see Fig. 4).

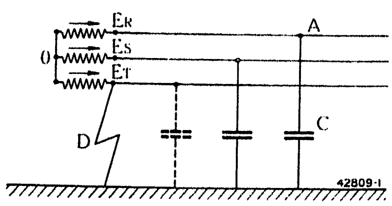

Fig. 4. — Reciprocal cancelling out of the third harmonics of the voltage in the earth circuit of a network with insulated neutral, under unsound conditions (fault to earth on one phase).

E_R, E_S, E_T. Instantaneous values of third harmonics of the voltage in the three phases.
D. Fault to earth.
C. Capacity of one phase referred to earth.
OACDO. Earth circuit.

On the other hand, the current of the other har-

monics, as well as that of the star system of triple frequency and that of the fundamental wave close through the fault and the defective phase (Fig. 5).

If the circuit OACDEO, for example, is followed out, it will be noted that the two E. M. F. of the said circuit, OR and OT produce a resultant E. M. F. which is TR that causes the current of the harmonic under consideration to circulate in the circuit. At the point of fault, there is the geometrical sum of the capacitive earth current produced by the two sound phases, which is $\sqrt{3}$ times the phase current. If the value of the voltage harmonic of the n^{th} order be designated by a, expressed in % of the fundamental wave, the current of harmonic n from a sound phase is $J_{cn} = a \times E \times \sqrt{3} \times n \times \omega \times C = a \times n \times E \times \sqrt{3} \times \omega \times C$ in which $E\sqrt{3}$ is the line voltage, C the capacity of that phase to earth. Now $E \times \sqrt{3} \times \omega \times C$ is the current of fundamental frequency J_c in a phase, therefore $J_{cn} = a \times n \times J_c$. The current of harmonic n at the faulty point will be J_{cn} total $= J_{cn} \times \sqrt{3} = a \times n \times J_c \times \sqrt{3}$.

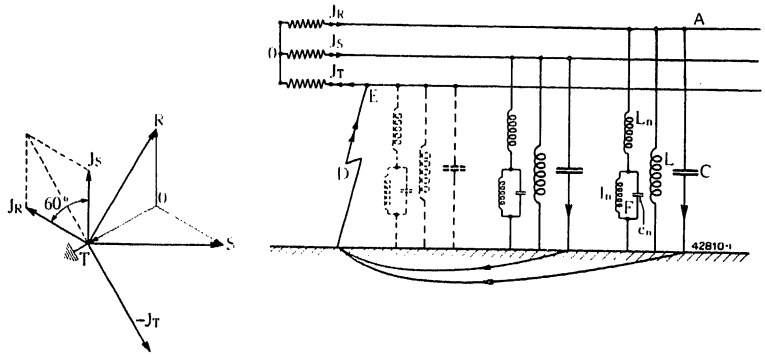

Fig. 5. Formations of the harmonic of the earth current, of order n other than 3, or of the star system of triple frequency, in a network with insulated neutral, under unsound conditions, and compensation of this harmonic.

J_R, J_S, J_T. Instantaneous values, of the harmonics of orders other than 3, of the earth current, in the three phases.
C. Capacity of a phase referred to earth.
F. Electric filter which forms the additional compensating system with the coil L_n.
l_n. Inductor forming part of filter.
c_n. Capacity forming part of filter.
L_n. Inductor of the additional compensating system.
L. Compensating choke coil for the fundamental wave of the earth current.
D. Way to earth.
O A C D O. Earth circuit.
OR, OS, OT. Amplitudes of the nth harmonics of the voltage in the three phases (of order other than 3).

b) *The neutral of the network is straight earthed.* The third harmonic of the damaged phase (Fig. 11) closes through the fault and the neutral point; that of two sound phases through the capacity referred to earth and the neutral. The other harmonics close through their capacities to earth, their circuits being completed by the fault.

This case has little practical value as, where an earth occurs, the line affected must be cut out, immediately.

c) *The neutral of the network is earthed through an extinguishing coil.*

1. The third harmonic of the current closes through the coil.
2. The other harmonics of the current close through the fault, as under a. The presence of the extinguishing coil makes no difference to their distribution.

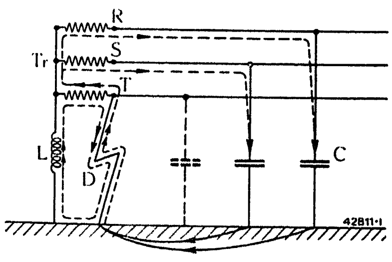

Fig. 6. — Compensation of the fundamental wave of the earth current under unsound conditions.

R, S, T. Three-phase network.
Tr. Supplying transformer.
C. Capacity of a network phase referred to earth.
L. Compensating inductor.
D. Earth fault.

IV. METHOD OF COMPENSATING HARMONICS.

The method is dictated by the circuit they follow. We will first study compensation under unsound conditions, because it is generally in case of an earth fault that the capacitive current to earth and its harmonics are the most troublesome.

A. *Compensation under unsound conditions.*

a) *The neutral of the network is insulated.*

1. There is no third harmonic.
2. The compensation of harmonics of other orders than 3 is carried out in similar manner to that applied for the fundamental current.

Let us recall the principle on which this is done. The neutral of the system being assumed to be insulated, this compensation cannot be effected by placing an inductor coil on the neutral. It is, therefore, necessary to insert an inductor coil equal to the capacity of the phase, on each phase (see Fig. 7). This inductor produces an inductive current in each phase which is always equal to the capacitive current of the phase in question.

This inductor is designed with a considerable air gap distributed over the length of the magnetic circuit. Owing to this factor, its induction curve is, nearly, a straight line over the whole working range despite fairly heavy saturation. By this means, the desired reactance is attained economically and the double inconvenience inherent to a highly saturated inductor is avoided, namely:— creation of a new harmonic of

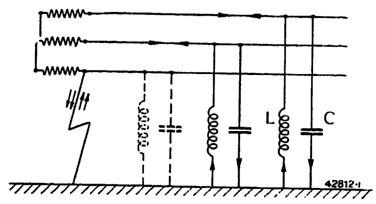

Fig. 7. — Compensation of the fundamental wave of the earth current under sound and unsound conditions.

C. Capacity of a phase of the network referred to earth.
L. Compensating inductor.

the 3rd order in the system and big variation in the inductance according to the voltage applied (as, for example, in the case of an earth fault, when the voltage passes from the phase-voltage value to the line-voltage value).

However, this coil only compensates a very small fraction indeed of the earth current harmonics, because the reactance it opposes to a voltage of frequency nf is n times its reactance at the frequency f and the voltage applied across it is only a $^0/_0$ of its standard voltage. Expressed mathematically, the fraction compensated is as follows:—

It was shown that the harmonic of the n[th] order, at the fault, to be compensated is $J_{cn} = a \times n \times J_c \times \sqrt{3}$. The reactance of the coil at a frequency of f is $\frac{1}{\omega C}$; and at a frequency nf it becomes $\frac{n}{\omega C}$. The compensating current of nf frequency which it gives passage to at voltage $E_n = a \times E$ is

$$J_{bn} = \frac{a \times E}{\frac{n}{\omega C}} = \frac{a \times E \times \omega \times C}{n} = \frac{a}{n} \times J_c.$$

The compensated current is, thus, only

$$\frac{1}{n^2 \sqrt{3}}$$

times the current to be compensated. The harmonics must, therefore, be compensated separately. This is done by means of a system similar to that used for the fundamental current. Between each line and earth an additional system is connected, $F + L_n$ composed of inductors and capacities, which system is parallel to the inductor L which compensates the fundamental wave (see Fig. 5). The resultant inductance of this system is calculated so as to cause the formation of an inductive current of frequency nf equal to the capacitive current of the harmonic n. This current then neutralizes the earth harmonic in each phase.

The part of this additional system designed by F formed by the inductor l_n and the capacity c_n in parallel, plays the part of a screen to the passage of the fundamental wave current at f frequency. To this end, the inductance of coil l_n is made equal to the capacitance of the battery c_n for the frequency f; the resultant impedance is then, theoretically, of infinite magnitude for the frequency in question. The result is a resonant circuit similar to the "tuned circuit" utilized in radiophony. For the harmonic of the n[th] order, under consideration, i. e. for frequency nf, the inductance l_n becomes n times stronger and the capacitance of the battery c_n n times weaker, so that the total F has a low capacitance for the frequency nf. The group F becomes a filter which allows currents of frequency nf to pass, and is the designation given it in the following paragraphs. The inductor L_n in series with filter F is, then, calculated so that the additional system should have a suitable inductance at a frequency nf. Example I chapter V will show how the inductors and capacities can be determined.

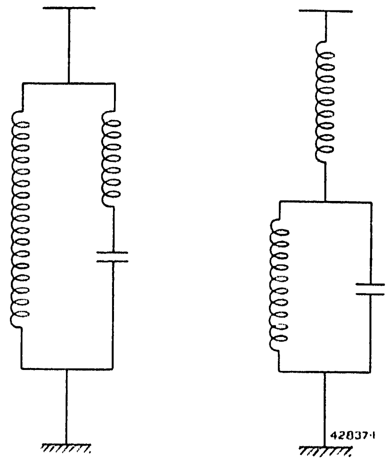

Fig. 8. — Compensating device for fundamental wave and harmonics.

It was shown, before, that if the neutral point is supposed insulated an inductor cannot be inserted on it to compensate the fundamental wave. However, there is no reason why an additional system of the $F + L_n$ type should not be inserted as it does not alter the state of insulation of the neutral point, this owing to the impedance of such a system being of infinite magnitude at the fundamental frequency. Thus, the harmonics can be compensated by an additional system between neutral and earth (Fig. 10) which is a cheap solution of the problem, as will be shown in the following paragraphs.

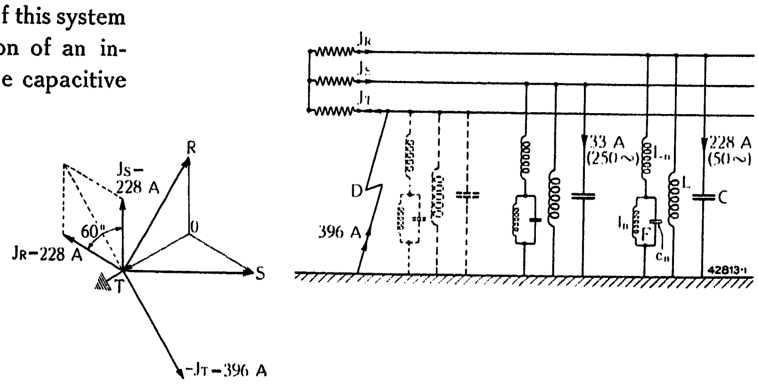

Fig. 9. — Compensation of the fifth harmonic of the earth current under sound and unsound conditions, in a network of cables with insulated neutral. Application of the general solution of Fig. 7.

J_R, J_S, J_T. Instantaneous values of the fifth harmonic of the earth current, in the three phases.
C. Capacity of a phase referred to earth.
F. Electric filter.
l_n. Choke coil forming part of the filter.
c_n. Capacity forming part of filter.
L_n. Inductor which forms, along with filter F, the additional compensating system.
D. Earth fault.
OR, OS, OT. Amplitude of fifth harmonic of the voltage in the three phases.

b) *The neutral of the network is earthed through an extinction coil.*

1. The third harmonic of the current closes through the extinction coil. Generally, however, the inductance which the coil opposes to this third harmonic is large enough to reduce this current to a low value, as can be seen from the two examples given, II. and III. at the end of this article. The said inductance is three times greater than for the current at fundamental frequency.

2. The other harmonics close through the fault, as does the current of fundamental frequency.

They are compensated in the same way as the fundamental frequency current by the extinction coil, itself. The principle is: — between neutral point and earth, an inductance is inserted which is about equal to the capacitance to earth of the three phases (see Fig. 6). This coil is under no voltage under sound conditions. When an earth fault occurs, it is subjected to the phase voltage. Under these conditions it causes an inductive current to flow through the fault and the defective phase, which current is equal to the fundamental wave of the total capacitive current caused by the two sound phases which follow the same circuit. The resultant is, therefore, zero at the faulty point and in the affected phase (leaving out of account the harmonics and the active current corresponding to the losses).

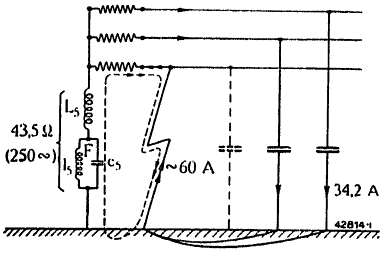

Fig. 10. — **Compensation of fifth harmonic of the earth current, under unsound conditions, in a network with insulated neutral point.**

F. Filter.
l_5, c_5. Inductor and capacity forming filter.
L_5. Inductor forming with filter F the additional compensating system.

This inductance coil is of similar design to those described under A, a. It, also, only compensates a very small fraction of the harmonics.

The latter must, thus, be compensated separately. To this end an additional system F + L_n is connected in parallel to the extinction coil, between neutral of network and earth. This system offers the harmonic of f n frequency an inductance of such magnitude as to generate at the fault an inductive current equal to the harmonic under consideration; as regards the fundamental frequency, the impedance of this system is theoretically of infinite magnitude; in other words, the inductance of the extinction coil is not affected. It should be noted that, contrary to compensation on each phase, the compensation on the neutral is only active in case of trouble and is inactive when the system is sound.

3. As regards the star system of triple frequency, caused by an accidental earthing on one phase, it should be added that it does not appear when the network is equipped with an extinguishing coil, as the latter eliminates the asymmetry of capacitive load, provoked by the accidental earthing, this by superimposing an inductive load of equal magnitude on the capacitive load; in other words, the extinction coil suppresses the cause of this star system of triple frequency. Recent tests made on earthings on a 50-kV network confirmed this. The earth current which revealed a current of triple frequency amounting to 40 A, before the network was compensated, that is of a value of 20 % of the total earth current, which was 200 A, revealed hardly a trace, once the extinction coils were put in.

B. *Compensation under unsound and sound conditions.*

It may be considered desirable to compensate the capacitive current even under sound conditions, when it is very strong. This is likely to be chiefly in a cable network at very high voltage.

The fundamental current closes through the capacities referred to earth, which form a star system (see Fig. 1).

It is useless to try to compensate this current by an inductor (extinction coil) inserted on the neutral, as current only flows through the latter coil in the case of an earth fault (unsound conditions). Thus, the neutral of the network remains insulated and *this is the only case considered here.*

1. The neutral being insulated, the third harmonic does not appear.
2. The other harmonics follow the same circuit as the fundamental current and are compensated in similar manner.

The fundamental current is compensated in the following way:— an inductor is placed on each phase, and is made equal to the capacitance of this phase (see Fig. 7). This inductor produces an inductive current in each phase equal, at each instant, to the capacitive current of the same phase. Whether the network is sound or affected by an earth fault, the compensation is correct. In both cases, the coils are subjected to the same voltage as the capacity of the phases to be compensated, that is to the phase voltage under sound conditions and to the line voltage when the fault occurs. Thus, the inductive current will, always, be equal and contrary to the capacitive current of the system. These inductor coils only compensate a negligeable fraction of the harmonics.

To compensate the latter, exactly the same measures are taken as under A, a. An additional system F + L_n is connected in parallel to the coils compensating the funda-

mental wave, between each phase and the earth. This system is valid both for unsound and sound conditions.

It should be added that, in the majority of cases, it suffices that the harmonics in unsound state should be compensated, because their current is not strong enough to be troublesome when it only goes to earth through the capacities of the system. It may affect arc extinction adversely by an increase of the residual current, only when it circulates through the fault.

The compensation of the harmonics under sound conditions is an expensive matter; it entails three additional systems, one per phase, dimensioned for the line voltage. On the other hand compensation under unsound conditions alone, only, can be carried out by an additional system at the neutral point, dimensioned for phase voltage, as was explained a few paragraphs before.

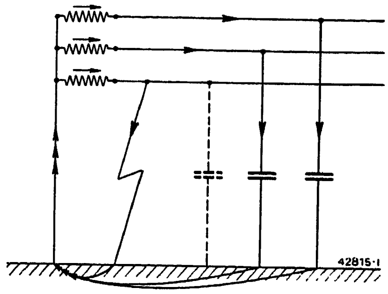

Fig. 11. — Formation of 3rd harmonic of the earth current in a network with neutral connected straight to earth; under unsound conditions.

It has also been suggested to use a system formed of two choke coils and a capacity, connected according to one of the diagrams of Fig. 8 and so calculated that it takes over, at the same time, the compensation of one (or two) harmonics and of the fundamental wave.

This method does not seem suitable to us. Calculation shows, namely, that the system in question is, at least, as expensive, if not more so, than the fundamental coil and additional equipment together. It would, thus, be necessary to incur, from the first, the expense of apparatus for the fundamental wave and for the harmonics. It, however, often happens that it suffices to compensate the fundamental wave in order to make certain of extinguishing the arc, thus making the additional equipment superfluous.

It is advisable, therefore, to first put in a single coil for the fundamental wave and then to observe the behaviour of the system in operation. Technically, it is better to put in two separate devices in order to make it possible to regulate them independently — by tappings for example — or to cut one out without throwing the whole compensation out of tune.

V. EXAMPLES.

It was shown that with the hypothesis of the neutral being insulated, there is only one system of harmonic compensation both for a sound or unsound network. Example I will, therefore, suffice to illustrate Chapter IV, A and B.

Example I. Compensation of the harmonics in a network with insulated neutral point.

On a transmission line at 150 kV composed of three single-phase cables of the oil-insulated type, 22 km long, the capacitive current per phase, at frequency f, attains 132 A under ordinary service conditions. In the case of a fault to earth on one phase, the capacitive current of each of the two remaining sound phases rises to 228 A. These two currents close over the fault and have a 60° phase difference (Fig. 9). The total capacitive current over the fault and at frequency f is, thus, $228 \times \sqrt{3} = 396$ A.

It may appear desirable to compensate capacitive currents of f frequency, of this strength, even under sound conditions, on account of the capacitive loading capacity of the cables. As was explained before, the compensation consists in putting an inductor L between each phase and earth, dimensioned for 150 kV, 228 A, 660 ohms at 50 cycles. Assuming now that the analysis of the voltage curve of the network reveals the presence in it of a harmonic of the 5th order, the value of which is a = 3% of the fundamental wave, i. e. 4500 V, the harmonic current of 5th order in each phase will be: $I_{c5} = a \times n \times I_c = 0{\cdot}03 \times 5 \times 228 = 34{\cdot}2$ A. The main inductor coil L has a reactance $5 \times 660 = 3300$ ohms with reference to this 5th harmonic. The fraction of the above harmonic current compensated by the main inductor will only be, therefore, $\frac{4500\ \text{V}}{3300\ \text{ohms}} = 1{\cdot}36$ A.

This is an insignificant fraction to be compensated. There still remains about 33 A per phase which has to be compensated by an additional system.

If it is desired to compensate the harmonics under sound conditions, as well, the system will comprise, per phase a filter F (capacity c_n and induction l_n in parallel) and an inductor L_n in series. The resultant inductance will have to be $\frac{4500\ \text{V}}{33\ \text{A}} = 137$ ohms at 250 cycles. The inductor l_n and the capacity c_n will be designed for an inductance and capacitance such that they are of equal magnitude at 50 cycles. The resultant impedance of the filter being, then, theoretically, of infinite magnitude, as regards a frequency of 50 cycles the whole fundamental voltage to which the additional system is subjected in case of an accidental earthing, 150 kV, will appear across the terminals of the filter, that is to say the inductor l_n and the capacity c_n will be subjected to 150 kV.

The object will be, therefore, to give l_n and c_n an ohmic value, at 50 cycles, which will be as high as possible in order to limit to as low a figure as is feasible the current circulating in the circuit l_n—c_n due to the fundamental 150 kV voltage, and, consequently, to reduce as far as is feasible the power of the two elements of the filter system F at 50 cycles.

If the minimum power of each of the two elements is expressed in function of their impedance, we get:—

$$P_{50} = \frac{150{,}000\ \text{V}}{x} \times 150{,}000\ \text{V} = \frac{15^2 \times 10^8}{x}\ \text{VA} \quad (1)$$

$x = \omega \times l_n = \frac{1}{\omega\, c_n}$ = value of the inductance l_n in ohms or of the capacitance c_n at 50 cycles.

The value of x in ohms is limited, on the other hand, by the voltage at the terminals of the system F, which creates the circulation of the compensating current of frequency 5f, namely 33 A, or in other words, by the power of the element c_n of the system F at 250 cycles (the element l_n has a very high inductance at 250 cycles, so that nearly all the current 33 A passes through c_n and the power of l_n at 250 cycles remains low).

If the power of the element c_n at 250 cycles is also expressed in function of x the following equation is reached:—

$$P_{250} = \frac{x}{5} \times i_{c\,250} \times i_{c\,250} = \frac{x}{5} \times (i_{c\,250})^2 \text{ VA} \qquad (1\,a)$$

$i_{c\,250}$ = current in c_n at 250 cycles.

The value of $i_{c\,250}$ is determined as follows:— the 33 A current divides up between a reactance $+(5x)$ and a capacitance $-\left(\frac{x}{5}\right)$ therefore: —

$$i_{c\,250} = 33 \times \frac{5\,x}{5\,x + \left(-\frac{x}{5}\right)} = 33 \times \frac{25}{24} = 34 \cdot 37 \text{ A}$$

and $$\underline{P_{250}} = \frac{x}{5} \times 34 \cdot 37^2 = \underline{\frac{x}{5} \times 1 \cdot 18 \times 10^3 \text{ VA}} \qquad (2)$$

The optimal value of x will be that corresponding to the minimum of the sum $P = P_{50} + P_{250}$.

A given condenser battery, built for 50 cycles can provide, at 250 cycles, approximately a power 2·5 times greater than at 50 cycles without being damaged, to this end it is sufficient to increase the cooling surface of the tank, for example; this ratio can, therefore, be introduced into the expression of P.

$$P = 2 \cdot 5 \times P_{50} + P_{250} =$$

$$2 \cdot 5 \frac{1}{x} \times 15^2 \times 10^8 + \frac{x}{5} \times 1 \cdot 18 \times 10^3.$$

The most advantageous value of x is obtained by deferentiating and setting down $\frac{dP}{dx} = 0$; the calculation gives

$$x = 15{,}500 \text{ ohms.}$$

The inductance l_5 and the capacity c_5 will, thus, be designed for an inductance of + 15,500 ohms and a capacitance of − 15,500 ohms at 50 cycles. Their resultant impedance will be infinite at 50 cycles, theoretically. The filter system F will block the passage of the fundamental current, but a current of $\frac{150{,}000 \text{ V}}{15{,}500 \text{ ohms}} = 9 \cdot 7$ A will pass through the circuits l_n c_n.

The battery and the inductor will each have a power of 9·7 A × 150 kV = 1460 kVA. At 250 cycles, the inductance of l_n becomes + 78,500 ohms; the capacitance of c_n, − 3100 ohms, and the impedance of $F = \frac{78{,}500 \times (-3100)}{78{,}500 + (-3100)} = -3220$ ohms. The impedance of l_n at 250 cycles should be + 3357 ohms if the compensation system is to have a resultant impedance of + 137 ohms, as required. The voltage across the battery terminals will be 3100 ohms × 34·37 A = 106·5 kV and its power 106·5 × 34·37 A = 3650 kVA. Thus, the battery should be designed for 1460 kVA at 50 cycles + 3650 kVA at 250 cycles.

To determine the output of the standard condenser battery to be chosen, the process is as follows:— the volume of the battery is a function of the thickness of the dielectric, i. e. of the total voltage applied, which latter results from the superimposing of the two voltages at 50 and 250 cycles. The total volume of the said battery, for a given capacity, increases with the square of this voltage.

If E designates the voltage at 50 cycles and e that at 250 cycles, the output of the standard type will be theoretically, $P = \frac{(E+e)^2}{E}$. $P_{50} = \frac{(150 + 106 \cdot 5)^2}{150} \times 1460 = 4260$ kVA.

In practice, because of the short duration of the peak voltage value at 250 cycles a specific load of greater magnitude can be allowed than at 50 cycles. The output of the standard size chosen will be about <u>3900 kVA.</u>

As regards the inductors l_n and L_n, their outputs can be deduced from that of the battery. The important factor to be determined was the minimum output of the battery as its cost per kVA is from 2·5 to 3 times higher than that of an inductor of same output.

The inductor l_n will thus be designed for <u>1460 kVA</u> at 50 cycles, and L_n for 33 A × 3357 ohms = 111 kV, 3660 kVA at 250 cycles, which corresponds approximately to an induction of 1900 kVA at 50 cycles. In all, three l_n coils will be required, three L_n coils and three c_n batteries.

This shows that considerably powerful apparatus is necessary and that the compensation of harmonics, in this way, will cost as much as the compensation of the fundamental current.

As a rule, however, it will not be necessary and it will, generally, be found sufficient to insert one additional system, alone, L_5 + F between the neutral and the earth (Fig. 10). The total current of frequency 5 f to be produced at the fault is equal — if the small effect of the main coil or coils is disregarded — to the geometrical sum of the capacitive currents of the same frequency coming from the two sound phases:— $\sqrt{3} \times 34 \cdot 5 = 60$ A.

The fifth voltage harmonic to which the system is subjected, if an earth takes place, is $\frac{0 \cdot 03 \times 150{,}000}{\sqrt{3}} = 2610$ V. The inductance of the system will, therefore, be $\frac{2610 \text{ V}}{60 \text{ A}} = 43 \cdot 5$ ohms.

The coil l_5 and the capacity c_5 of the filter, determined by the preceding method will then be

+ 5000 ohms and — 5000 ohms at 50 cycles that is + 25,000 ohms and — 1000 ohms at 250 cycles. The resultant capacitance of the filter F will be —1040 ohms. The coil L_5 will have an inductance of + 1083·5 ohms. The whole apparatus will be composed of:—

1 inductor coil L_5 of 60 A, 65 kV, 3900 kVA at 250 cycles which corresponds to a coil of 2000 kVA at 50 cycles.

1 condenser battery c_5 of 1000 ohms, 62·4 A, 62·4 kV, 3900 kVA at 250 cycles and 5000 ohms, 17·4 A, 87 kV, 1515 kVA at 50 cycles, that is to say a total theoretical output of $\left(\frac{87 + 62{\cdot}4}{87}\right)^2 \times 1515 = 4460$ kVA.

The size of the standard condenser battery to be chosen will be about 4000 kVA.

An inductor coil l_5 of 5000 ohms, 17·4 A, 87 kV, 1515 kVA at 50 cycles.

The cost of this compensating system will be about 50 % of that of the compensating system of the fundamental current.

Example II. Effect of the extinction coil on the third harmonic.

An overhead network, 20,000 V, 50 cycles, has a total earthing current of 30 A, that is $30/\sqrt{3}$ A per phase. The reactance of the extinction coil at 50 cycles will be $\frac{20{,}000/\sqrt{3}}{30\ \text{A}} = 385$ ohms. As regards the third harmonic, this reactance will amount to 1155 ohms. If, now, the amplitude of the third harmonic of the voltage is 4 % of the fundamental wave, for example, that is 460 V, the third harmonic current which with a neutral straight earthed would be $0{\cdot}04 \times E \times 3 \times \omega \times C = \frac{0{\cdot}12 \times 30\ \text{A}}{\sqrt{3}} = 2{\cdot}08$ A at the fault that is to say 6·24 A at the neutral point, will only be $\frac{460\ \text{V}}{1155\ \text{ohms}} = 0{\cdot}4$ A at the fault and 0·45 A through the coil.

Example III. Another network.

Assuming the same underground cable line of 150 kV as in example I, if efforts are limited to eliminate the current at the fault, 396 A, in the case of an earthing, an inductive current must be superimposed on it which is produced by means of an inductor coil, placed on the neutral point. When an earthing takes place, this coil is subjected to the voltage induced in the unsound phase, it will, therefore, be dimensioned for 87,000 V and 396 A, that is for 220 ohms at 50 cycles.

This coil has an inductance of 660 ohms at 150 cycles. It is connected in series with the three capacities in parallel of the system, that is, with $\frac{220}{3} = 73{\cdot}3$ ohms. The resultant inductance of the circuit is, thus, $660 - 73{\cdot}3 = 586{\cdot}7$ ohms. If the value of the third harmonic is 4 % of the fundamental wave, for example, that being $0{\cdot}04 \times 87{,}000 = 3480$ V per phase, there will circulate through the coil a current of $\frac{3480\ \text{V}}{586{\cdot}7\ \text{ohms}} = 5{\cdot}93$ A. The harmonic of the current of the unsound phase passes through the fault, it being $\frac{3480}{660} = 5{\cdot}3$ A. This residual current on the fault caused by the third harmonic is, thus, hardly more than 1 % of the total current. It is hardly of the same order as the residual current of frequency f due to the margin allowed for compensation.

In any case, when dealing with a fundamental capacitive current of this importance, efforts are made to compensate it under sound conditions, as well. This causes an inductor to be inserted on each of the three phases instead of between the neutral point and the earth. The neutral remains insulated and the third harmonic circuit is not closed.

Example IV. Effect of the extinction coil on the fifth harmonic.

In example III, the inductor has 220 ohms at 50 cycles. At 250 cycles its inductance attains 1100 ohms.

The fifth voltage harmonic applied to it has an amplitude of $\frac{0{\cdot}03 \times 150{,}000}{\sqrt{3}} = 2610$ V. The coil, thus, only compensates $\frac{2610\ \text{V}}{1100\ \text{ohms}} = 2{\cdot}4$ A. The remainder must be compensated as before, that is, either by an additional system between each phase and earth or by one single additional system between the neutral point and the earth.

VI. CONCLUSIONS.

a) The compensation of the third harmonic of the capacitive earth current and multiples thereof can be disregarded; if the neutral is insulated, it cannot be formed; if the neutral is straight earthed, the damaged line must be cut out instantaneously when an earth fault occurs. If an extinction coil is inserted, the inductance of the said coil opposes itself to the formation of this third harmonic of the current.

b) Compensation of harmonics of other orders than 3, as well as that of the star system of triple frequency is carried out in the same way as for the fundamental current, by two different methods:— either by a compensating system between each phase and earth (in which case the compensation is efficient both for sound or for unsound network conditions), or by a compensating system between the neutral and the earth (in this case, compensation takes place only under unsound network conditions). This system of compensation forms a filter which allows current of nf frequency to pass but prevents the passage of current at the fundamental frequency.

Thanks to this compensation of the harmonics, it becomes possible to reduce considerably the residual current over the fault, in networks having a

strong earthing current (except the active current component) and thus to facilitate the extinction of the arc, in the case of an accidental earth.

As to the active current component, the following should be noted:— if, on the one hand, it cannot be asserted that the reduction of phase displacement between residual current and the voltage which creates same is of much importance in arc extinguishing (contrary to what occurs when an ordinary inductive circuit is opened by breaker, because, in the case considered, voltage only builds up again slowly on the faulty phase), it is, on the other hand, no obstacle, itself, to arc extinction because it is generally fairly weak in underground networks.

It might become dangerous only from a certain value upwards, of a magnitude practically solely encountered in networks with very weak insulation, or in which the transformers, the lines and the compensating coil offer a very high resistance, that is in networks in which the circuit of the earth current has a strong damping character. In this case alone, the building up again of the voltage on the damaged phase might be accelerated to such a degree as to attain a value sufficient to reignite the arc before the ionization of the arc track has disappeared. It can be shown that the speed of this voltage rebuilding is a function of the damping of the earth current circuit or, to put it otherwise, of the active-current component.

Practically, unless a supplementary resistance is inserted on the circuit, damping and the active current component is fairly low, so that the rebuilding of the voltage is slow and the arc does not reignite.

It should be remarked that the effect of the active component of the current is not the same in networks compensated by extinction coils as in non-compensated ones. In the latter, the voltage at the fault builds up again immediately after the current passes through zero. Reignition would be all the more to be feared the greater the phase displacement of the current on the voltage at the fault, because, in this case, the voltage has just attained its peak value which becomes immediately high at the moment the current passes through zero. The active component of the current will, thus, in itself, have a favorable influence as it tends to reduce the phase displacement of the resultant current at the fault. The said current passes through zero at the moment the voltage is far from having its peak value, which of course reduces the danger of reignition of the arc.

(MS 981) *A. Maret. (Mo.)*

SOME COMMENTS ON THE ERECTION OF BROWN BOVERI AIR-BLAST HIGH-SPEED CIRCUIT BREAKERS.

Example of a switching station.

Decimal index 621. 316. 57. 064. 45.

As is generally known, the air-blast high-speed circuit breaker has considerable advantages over other types of breaker as regards erection:— it demands neither special layout of the leads nor particular design and construction of the station proper.

There being no insulating mass or liquid extinguishing medium employed, this breaker can be mounted in any position:— vertically, horizontally, obliquely or even upside down (on the ceiling). Thus, the most suitable arrangement for each particular case can always be adopted, which is very advantageous in old plants being made over to meet modern conditions.

Further, the operation of the air-blast breaker is free from the production of soot or fumes and all danger of explosions or fires is eliminated. The building, therefore, has only to fulfil the duty of a protection for the material against unfavorable weather conditions, the parts carrying the breaker (building framework and iron work, etc.) being, obviously, made strong enough to withstand the static and dynamic stresses put on them by the weight and operation of the breakers, as is the case for any type of apparatus being installed. The layout and design of the substation can, thus, be based solely on considerations of service convenience and economy.

In existing plants, in which oil circuit breakers are to be replaced by stouter equipment, the safest solution, technically speaking, will be found to be the circuit breaker without oil; further, the air-blast breaker among the other apparatus which do not use oil will generally be found to allow of the most pleasing and the cheapest layout. The argument may be brought forward that modern oil circuit breakers are sufficiently compact to allow of their being

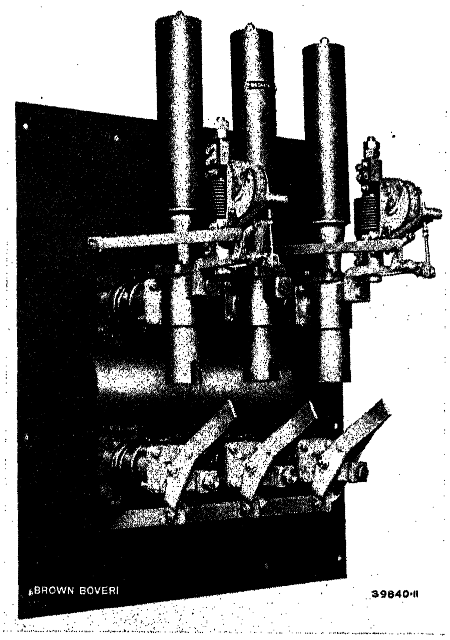

Fig. 1. — Air-blast high-speed circuit breaker with primary relay and sheet metal plate for mounting. View from high-voltage side.

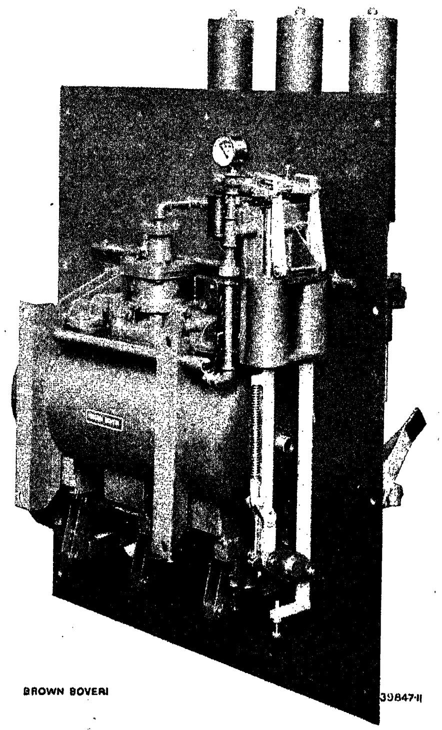

Fig. 2. — Air-blast high-speed circuit breaker shown in Fig. 1, seen from operating side.

put in, instead of air-blast circuit breakers and just as easily as the latter. It seems hardly necessary to recall that this can only be done at the risk of having apparatus mounted in an open hall which, whatever its qualities may be, cannot be claimed to be entirely exempt of all danger of fires and explosions. As is well known, a proper installation of oil circuit breakers, in order to be perfectly safe, must be carried out on the countersunk principle with cells entirely isolated from one another and, also, from the high-voltage plant. Further these cells must have communication to the outside. A layout of this kind is rarely possible of achievement in an existing building unless the latter is entirely made over, which means a big outlay of money.

Obviously, the erection facilities offered by air-blast breakers are best taken advantage of in quite new plants. The old layout of the station in cells can be eliminated as the dangers inherent to certain other types of breaker are absent here. The breakers can, thus, be put up side by side and without any partitions to separate them, in a hall type of chamber which contains all the high-voltage equipment. The advantages of a layout of this kind from the point of view of simplicity and ease of supervision as well as of economy in first costs and in upkeep are self-evident. Attendance and supervision of a plant of this type are easier than in one with cells and the possibilities of the faulty switching of disconnecting switches is, practically, eliminated, without using complicated signalling equipment or interlocks, which it is always advisable to do without, if possible. In order to isolate a circuit breaker from its neighbours, two portable partitions suffice, which can be added to the other spares in the plant.

In stations of this type, which may be termed open stations, there is a particularly interesting method of erection available:— this is mounting on a sheet metal plate, a method already referred to in this Review[1] and on which we republish two illustrations showing the principle applied. The plate separates the high-voltage part of the breaker from its operating mechanism. It, thus, prevents all accidental contacts with the high voltage while leaving the breaker perfectly accessible on either side.

Figs. 3 and 4 show two views of the Franière station, belonging to l'Union des Centrales Electriques du Hainaut, which is designed on the lines just described.

The station comprises nine panels, of which six are taken up by circuit breakers, one by voltage transformers, the two others being spares. The breakers are of 37-kV rated voltage and have a rupturing capacity of 500 MVA referred to the recovery voltage of 30 kV, which is the rated service one.

The architecture of the station is of great simplicity, and, despite general compactness, the whole is very spacious and airy, as is made clear by Figs. 3 and 4. The circuit breakers are mounted on plates of sheet metal which, in their turn, are secured to a metallic

[1] See The Brown Boveri Review, Nov. 1935, page 199.

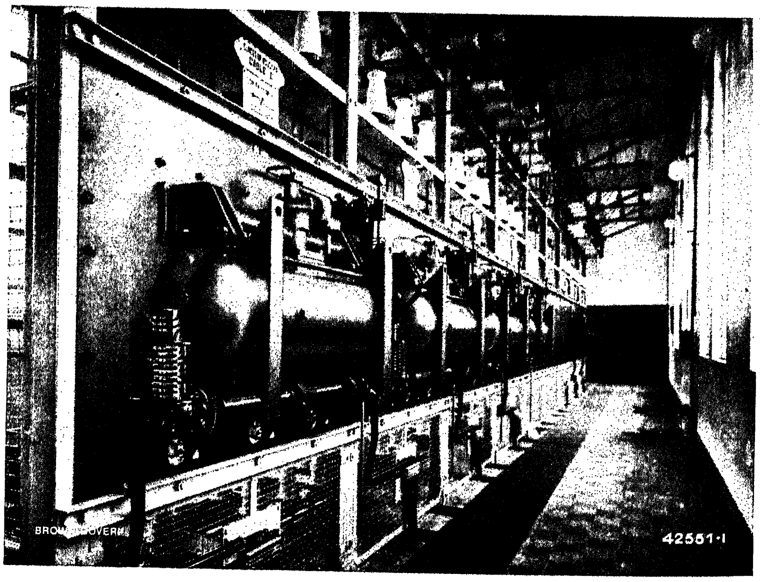

Fig. 3. — Union des Centrales Electriques du Hainaut, Franière station (Glaces de Saint-Gobain), equipped with six air-blast high-speed circuit breakers of Brown Boveri design, 37 kV, 500 MVA.

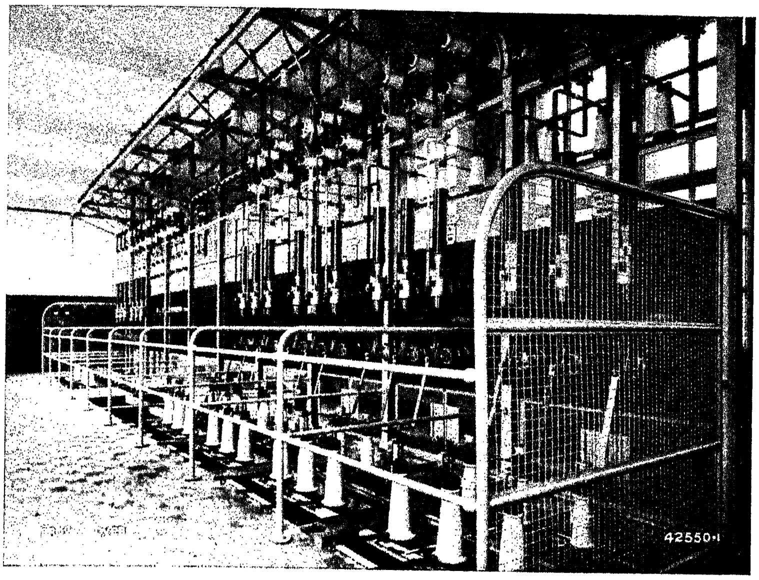

Fig. 4. — Franière station (Glaces de Saint-Gobain) of the U. C. E. H.

framewerk of very simple design and carrying, on both sides, the double set of busbars and the connections. In case of overhaulages, a set of metallic partitions on rollers has been provided which allow of isolating any one of the panels from its neighbours, after the portable safety guards of the different panels have been removed.

Apart from the operating, measurement and protection board seen in Figs. 3 and 4, the station comprises a double automatic plant for producing and distributing compressed air and a storage battery at 24 V for feeding the control, protection and signalling circuits. The building thus contains the complete plant with all its auxiliary services. In spite of there being two different sources of power, one pneumatic, the other electric, the plant of the auxiliary services does not take up too much room or complicate matters in the station, which is, partly, due to the simplicity of the air-blast circuit-breaker control and, partly, due to compressed air being a very convenient power agent indeed, as practical experience is showing more and more clearly.

(MS 504) *J. Defreyn. (Mo.)*

NOTES.

Another batch of eight express locomotives Type 2-Do-2 with Brown Boveri individual axle drive, for the Paris-Orléans-Midi Railway.

Decimal index 621. 335. 2 (44).

AT the end of March 1936, the Compagnie Electro-Mécanique, Paris got an order from the Paris-Orléans-Midi Railway for another batch of eight electric express locomotives. The locomotive design is always the same, namely Type 2-Do-2, for D. C. 1500 V, 4000 H.P., maximum speed 140 km/h (150 km/h exceptionally), which is the design that was first chosen in 1925 when only two test locomotives were ordered from the C. E. M. for the Paris-Orléans Railway (see The Brown Boveri Review, numbers 8 and 9, year 1927; number 6, year 1933; number 5, year 1934; number 4, year 1935). The type of driving motor is also the same as is the design of the drive itself (Brown Boveri individual axle drive, outside the frame of the locomotive proper) and the bogie design. Details, only, both on the electrical and mechanical side, have been altered as regards design or importance, from one batch of locomotives to another. Thus, for example, this last batch of eight locomotives (bearing numbers 538 to 545) are not built for power recuperation because, for the present, they are not intended for hilly line sections, but for service on the St. Pierre des Corps (Tours)-Bordeaux section which is to be electrified and made ready for service in the year 1938. However, the new locomotives are to be built so that there will be no difficulty in equipping them, subsequently, with the apparatus and machines for power recuperation.

The mechanical part of these eight machines will be built by the Compagnie de Fives-Lille in their Fives shops. The motors of three locomotives will also be built by the Cie. de Fives-Lille in the Givors shops, according to C. E. M. drawings. All individual axle drives will be built by the C. E. M. in Le Bourget and the rest of the electrical equipment in their Le Havre shops.

On this subject, it may be said that, according to the 1936 summer time-table, train No. 7 (South Express) covers the 112-km line section Les Aubrais-St. Pierre des Corps (Tours) in 58 minutes, corresponding to an average speed of 115·9 km/h. This is a record, in France, for all steam and electric trains. The maximum speed reached on this line section is 130 km/h. These expresses are always drawn by the 2-Do-2 locomotives, of the type for which the above repeat order has been placed.

The new order increases the total number of locomotives of this series, in France, to 68.

(MS 502) *E. Schroeder. (Mo.)*

Individual electric drive of cotton cards.

Decimal index 621. 34 : 677. 051. 4.

THE essential problem in the drive of cards in fine-cotton spinning mills is to accelerate smoothly and several times a day, the card cylinder, up to 170 to 220 r. p. m., the latter representing a moment of inertia of from 500 to 800 kgm^2. After starting, the above-mentioned operating speed must be maintained as closely as possible, at a power input of about 1 kW. In order that the starting period should be as short as possible and operation economical, the driving motor must possess a high starting torque and good efficiency. Further, special stripping brushes have to be driven which are used for the regular and frequent stripping of the carding-cylinder clothing. To carry out the periodical but less frequent grinding of the latter, the card has to be driven in counter sense. These requirements are simple in themselves but it must be remembered that there

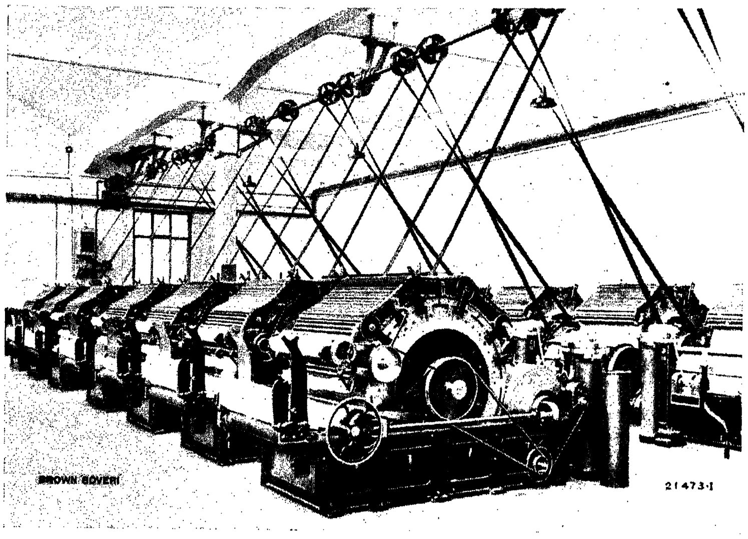

Fig. 1. — Carding room with group drive of cards by a line shaft directly coupled to a geared motor.

are a great number of cards in the mill, as compared to the other spinning machines, that they take up considerable space and are placed very close to one another (Fig. 1). For this reason, the driving motors cannot be placed alongside the machines. The problem to be solved is the lodging of the motor in a very restricted space which, usually, means making some constructive alterations to the machines (Fig. 2).

Brown Boveri was the first firm to solve this problem and delivered, as early as 1906, thirty card drives to a Brazilian cotton mill, which had decided to adopt the individual-drive principle exclusively.

If the individual drive of cards has only come to the fore, recently, this is due, less to there not having been a satisfactory solution of the question available, than to the slight interest manifested towards the individual drive of cards. The same far-reaching improvements in operation and attendance which accompanied the application of individual drive to other spinning machines, was not expected from the individual drive of cards, which machines are infrequently started and always run at constant speed. Group drive was, therefore, adhered to and this all the more so as the problem could, often, be solved with very simple transmission gear. Fig. 1, for example, shows a well laid out group drive; there is a geared motor drive composed of a high-speed motor and a reduction gear lodged in the bearing shield on the driving side, and this is direct-coupled to the line shaft at 250 r. p. m. Drives like this give good results. Nevertheless, individual drive has been attracting increasing attention of late. The better lighting and easier supervision and the reduction in dust resulting from the elimination of the line-shaft transmission gear cannot fail to react favorably on the production figures of cards. It is also of importance whether the operating speed of all cards is exactly maintained or not. Investigation in spinning mills with line-shaft transmission showed that there were speed deviations of 2—4 %, usually due to the different states of the transmission belts. Now, this is no poor result but means, nevertheless, that individual drive at exactly maintained speeds must lead to greater production.

If these qualities of individual drive are to be taken advantage of, the power transmission must take place with as small a slip as possible, this apart from the requisite electrical conditions which the motor has to fulfil and which have been mentioned already. The condition of no slip is best fulfilled by using a roller-chain drive which also produces smooth running of the driven machine and permits of bringing the two shafts very close together. Thus, the motor can be lodged in the card bend and close to the bearing of the cylinder (Fig. 2). The motor is secured to the card frame by a cast-iron support and does not project beyond the said frame. A totally-enclosed loom motor is used with grease-lubricated roller bearings which, practically, requires no attendance. The chain runs in an enclosed oil bath. The hand-operated motor-protection switch with thermal release is also built on to the machine; it connects the motor straight to the supply system. The card is rapidly brought to its full speed, the starting time being, always, about the same and shorter than with line-shaft transmission with which starting depends on the way the operation is carried out and which may last for a minute or more. The hand-operated protective switch can be replaced by one having solenoid control and push-button operation. The card shown in Fig. 2 is one of a big series of similar machines having metallic clothing and does not require grinding.

Machines with wire clothing are reversed when grinding is necessary, this

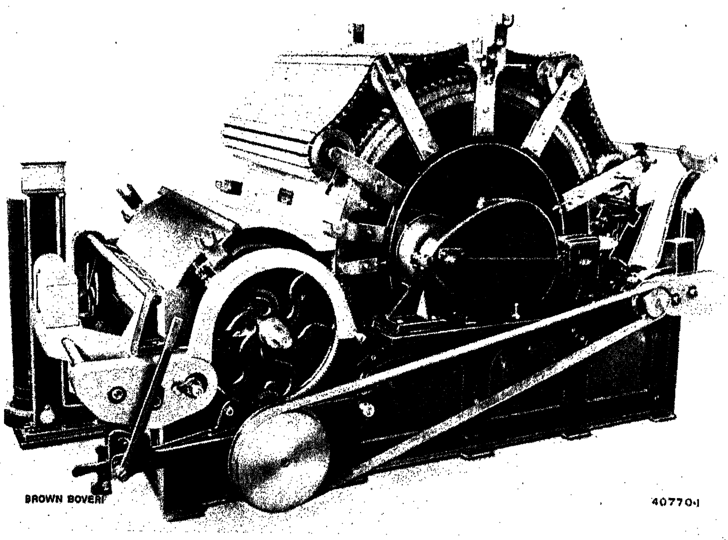

Fig. 2. — Card with individual drive by a built-in motor and chain.

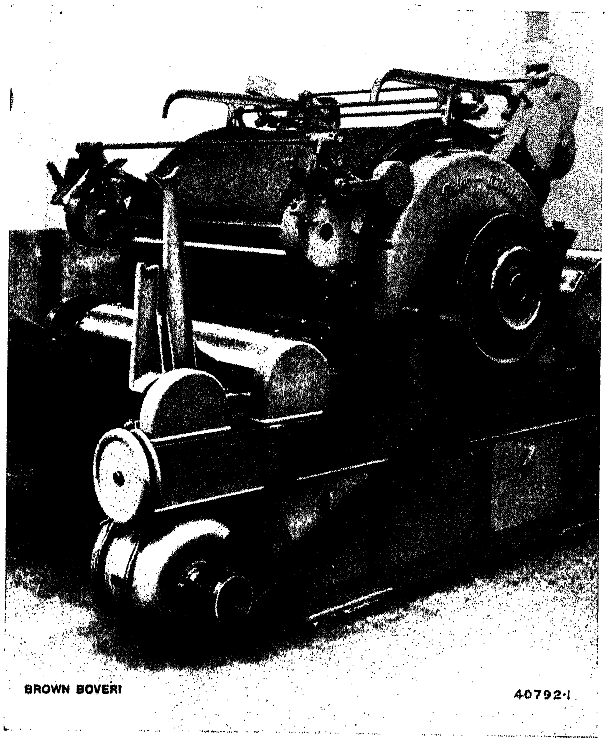

Fig. 3. — Card with individual drive by a cradled motor and belt.

being carried out by a change-over reversing switch which causes the motor to rotate in the opposite sense. The troublesome crossing of transmission belts which is necessary with line-shaft transmission is eliminated. The reversing position of the switch is interlocked and can only be released by the operator affected to this work. When stripping the clothing of the cylinder the motor shaft end which projects from the chain box, and is protected in ordinary service, is now used to mount a cable pulley to drive the cleaning brushes. The grinding cylinders can, also, be driven by this pulley. It should be mentioned that a horizontal or downward-inclined chain or belt is advantageous. This eliminates the danger of the card cylinder being lifted during starting and the cylinder clothing and the revolving flats harming each other by coming into contact. For this reason, motors mounted above the card are not recommendable.

The individual belt drive of Fig. 3 takes this into account. The motor is lodged at the bottom of the card frame and secured in a cradle under the feed roller. The necessary belt pull for efficient transmission is generated by the weight of the motor, itself and can be adjusted by a belt-tightning device, through springs. The springs impart a certain elasticity to the motor cradling. The stripping brushes are driven by the cylinder belt pulley which has a groove on the outside for this purpose. The grinding cylinders are driven in similar manner from the other side of the card, for which work the motor is reversed.

The numerous drives delivered in both the designs described have given an excellent account of themselves and the good results attained leave no doubt that individual drive of cotton cards is justified.

(MS 505) *H. Wildhaber. (Mo.)*

Plants for calibrating meters.

Decimal index 621.317.785.0014.

SPECIAL generators are required for testing and calibrating the meters used for measuring the electrical energy delivered from power stations or taken by power consumers. The motor type of meter used, to-day, for D. C. and the induction type of meter for A. C. requires two separate coil systems for measuring the quantities of electricity passed; one of these is termed the voltage coil because a current tapped across the voltage flows through it and the other the current coil, because the load current flows through it.

This subdivision of the winding systems of the meter makes it expedient to divide the calibrating machine into a voltage generator and a current generator. By dividing the calibrating machine into two units and by suitable choice of the electrical characteristics of the said machines, the calibrating set can be dimensioned for a smaller output than would otherwise be necessary for calibrating the meters. The voltage generator is dimensioned for the standard voltages encountered and for low current and the current generator for the highest service current encountered and for low voltage.

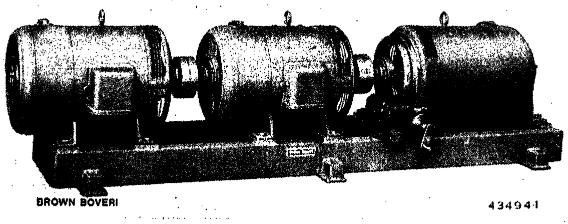

Fig. 1. — Calibrating set for meters, voltage generator 0·9/1·4 kVA, 380 V ± 10%. Current generator 0·86/1·7 kVA, 16·5/33·5 V, 1200/1800 r. p. m., 40/60 cycles.

Fig. 1 shows the set delivered by Brown Boveri to the Burgdorf Technicum (Technical School) and designed for calibrating A. C. meters. The set is composed of a D. C. motor, a voltage generator and a current generator.

In order to be able to calibrate the meters for the different power factors most common in practice, the voltage generator is designed with a stator to which an angular displacement can be imparted. This design allows of adjusting the phase displacement between current and voltage in a range of ±90

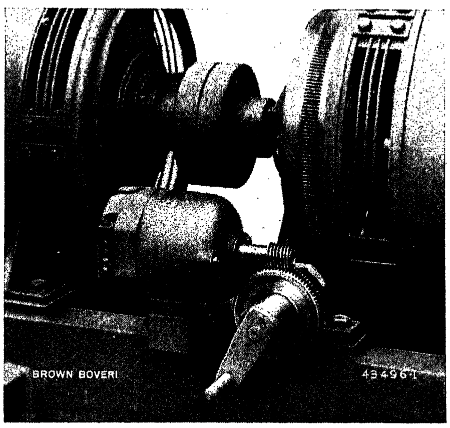

Fig. 2. — Device for the angular displacement of the stator of the voltage generator.

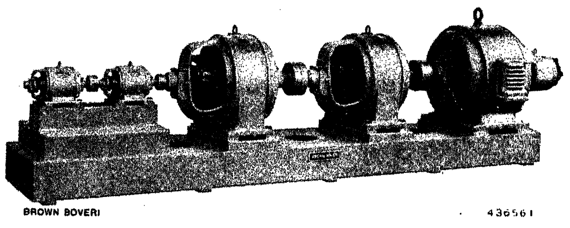

Fig. 3. — Motor-generator set for 2×22 kW at 2×125 V.

electrical degrees without requiring an induction regulator. The stator can be displaced by hand, on the machine, itself, or else, from a distance, through the agency of an auxiliary motor. The displacement gear is shown in Fig. 2. Further, in designing the set great care was devoted to making the voltage of the individual phases of one machine as equal as possible and to obtaining a practically sine form for the curve of the voltages generated.

Calibration of a three-phase meter requires that, during the time calibrating is being carried out, the voltage adjusted to and the frequency to which the meters are connected up should be maintained constant. This requirement can be met by driving the calibrating generators by a D. C. motor which draws its power from a source at practically constant voltage. In most cases, a storage battery is used, but this is an expensive solution and the cause of considerable outlay, in service. The tendency, in recent years, has been to replace the storage battery by a motor-generator set, the voltage on the D. C. side of which is maintained constant by an automatic regulating device. It is recommendable that the generator which is being used as a source of power for the calibrating set, should be separately excited and that it be coupled to a three-phase synchronous motor or three-phase induction motor. In the case of the synchronous motor, the regulating device has only got to be dimensioned for varying the excitation between no-load and full-load of the set while, in the case of the induction motor, an additional difference in excitation, to compensate the slip of the motor, has to be taken into account.

Fig. 3 shows the motor-generator set delivered by Brown Boveri to the Landis & Gyr Co., in Zug, the duty of which is to replace as a D. C. source a part of the storage battery in the calibrating station of the firm in question. The machine set comprises a three-phase synchronous motor and two D. C. generators each for 22 kW. The D. C. machines supply the three-wire D. C. system, 2×125 V which delivers current to the calibrating sets.

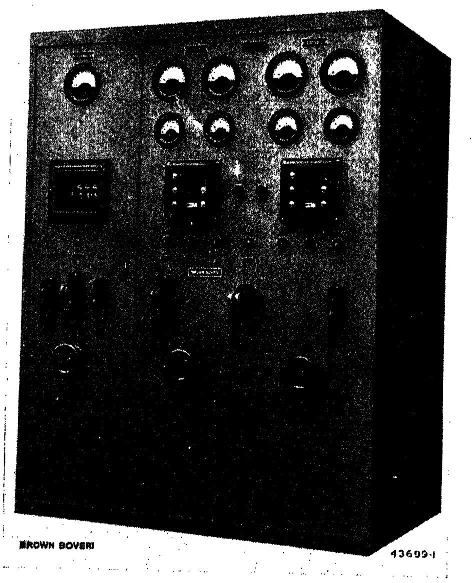

Fig. 4. — Switchgear for the 2×22 kW motor-generator set.

The switchgear belonging thereto was also supplied by Brown Boveri and equipped with a valve-type regulating device of Philips-Lamp Co. design (Fig. 4).

The tests carried out on the test bed showed that the voltage, once adjusted on the D. C. generators is maintained constant within a margin of less than 1 ‰.

For smaller plants instead of having two calibrating generators, a motor-generator set composed of an induction motor and a single D. C. generator suffices for the calibrating of D. C. meters while, for A. C. meters, a synchronous motor and a single three-phase generator can be used. The three-phase voltage can be transformed to the electric values suitable to calibrating by means of current and voltage transformers while an induction regulator is used to set the power factor.

Practice has shown that motor-generator sets with automatically constantly maintained voltage, are more suitable than storage batteries for supplying calibrating sets.

(MS 998) *von Escher. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2) : 621.313.322.

IN the year 1898, Brown Boveri delivered three three-phase A. C. alternators each for 170 kVA rated output, 750 V, 130 A, 32·5 cycles, 650 r. p. m., to the Stansstad-Engelberg Railway Co. These machines, of the well-known W6 type, had rotating armatures and 6 fixed field poles. Since they were put into service, these generators have run

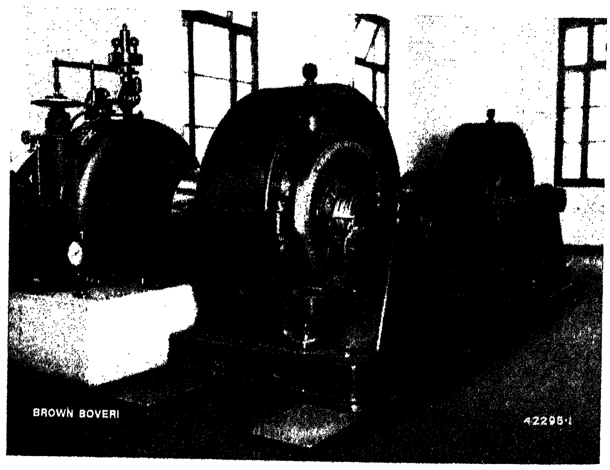

Fig. 1. — Stansstad-Engelberg Railway Co. Power station showing generators which date from the year 1898.

to the complete satisfaction of the company. No major repairs have ever been called for and the original carbon brushes delivered with the machines are still in use to-day.

The accompanying illustration shows the inside of the power station with two generator; the photo was taken at the time the plant was set to work.

(MS 994) *Prop.*

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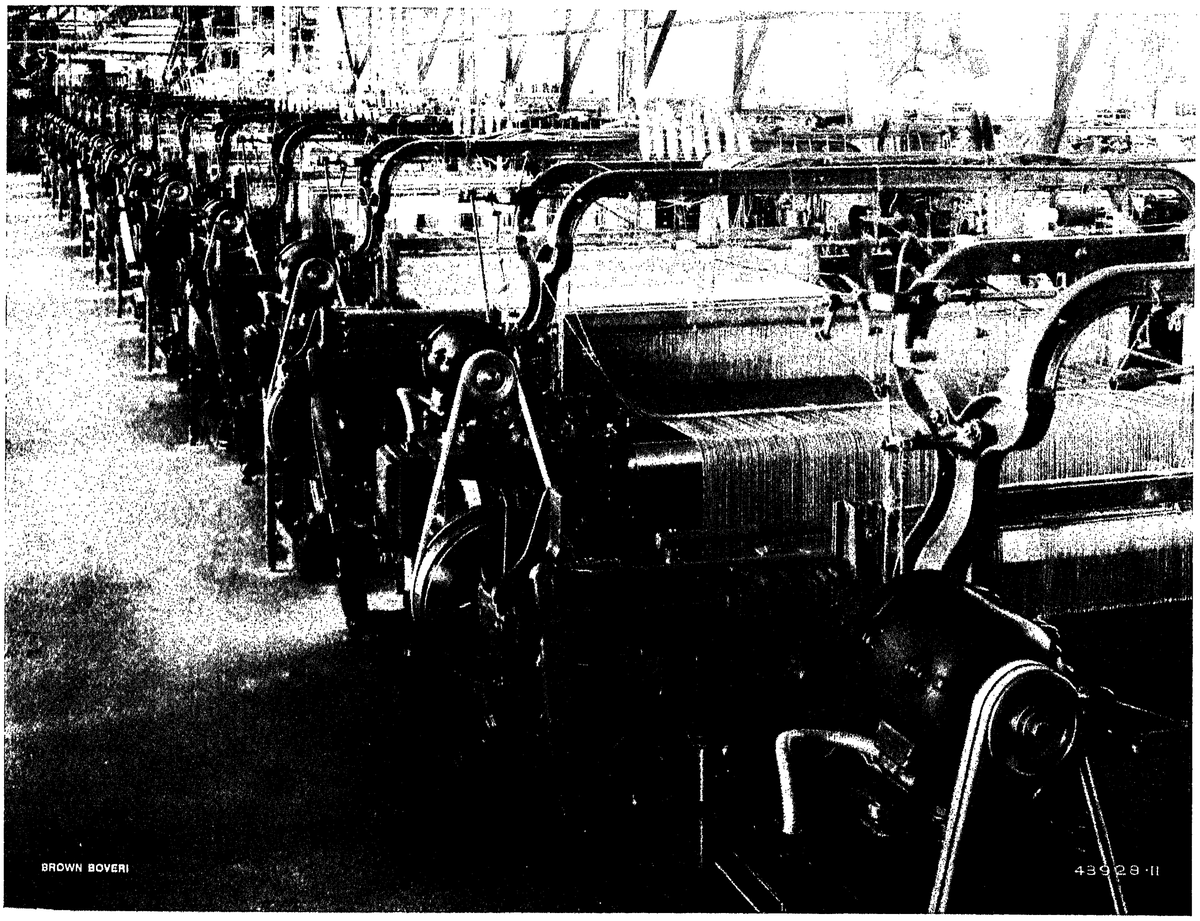

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Woollen looms with individual drive by loom motors, Type MW 126a, with adjustable cradle.

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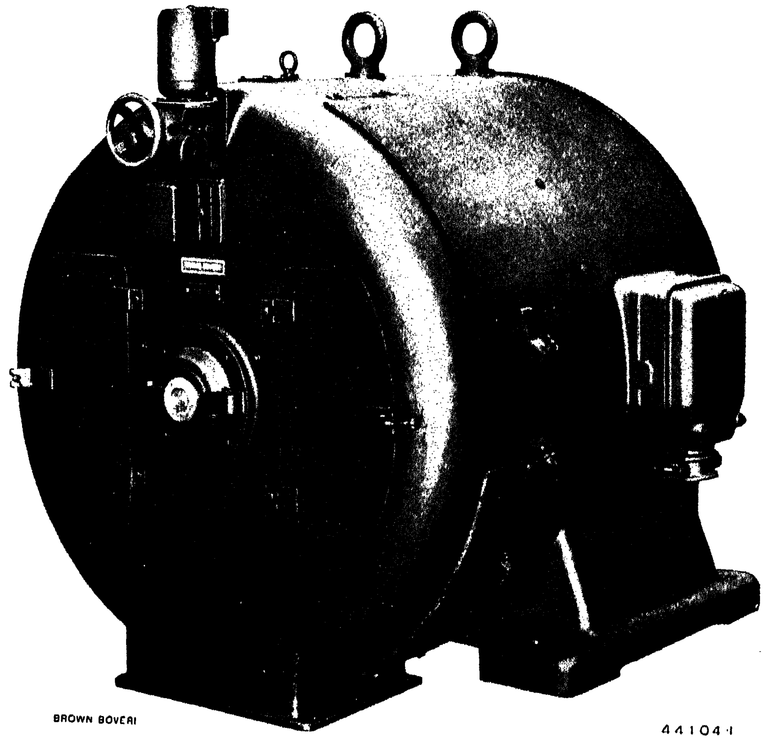
THREE-PHASE SHUNT COMMUTATOR MOTOR



for

Drives requiring smooth speed variation over a wide range, without losses

Speed independent of load fluctuations

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIII DECEMBER, 1936 No. 12

OVERHEAD LINES SUBJECTED TO THE ACTION OF HOAR FROST.

Decimal index 551. 574.

THE Compagnie Hydroélectrique d'Auvergne is the concessionary of a certain number of rural electrical syndicates located in mountainous country, at altitudes between 700 and 1300 metres.

This is country where hoar frost and ice formations on lines are much in evidence at certain periods and electric lines calculated strictly to the factors of safety applied in ordinary cases would run the risk of serious damage, under the effect of the exceptional overloads the conductors have to stand up to. This, in turn, would mean frequent trouble in service and, even, the total break down of power supply.

In agreement with the electrical syndicates, the lines were built to withstand hoar-frost loads forming round the conductors.

In studying the project of the system to be put up, the Cie Hydroélectrique d'Auvergne used the following data as basis for their investigations, this from the year 1928 onward.

(a) Maximum diameter of the ice sleeve measured on transmission and distribution lines in the region under consideration for a certain number of years.

(b) Maximum overloads noted in the same region.

(c) Values assumed by the Postal Telegraph and Telephone Administration.

Unfortunately, the overloads noted since the period in question were considerably greater than those taken into account in building the lines.

A great number of defective lines had, in consequence, to be rebuilt every year up till 1935, and this several times, despite the fact that stronger and stronger constructions were used.

The winter of 1935-1936 was not severe and it is thought that the climatic phenomena to which many parts of the Massif Central of France has been subjected for seven years running and, especially, during the winters of 1929/1930 and 1933/1934, represented the peak of a long cycle. Fig. 1 shows the country side of Cantal in February 1935, the trees loaded with hoar frost are all distorted, and it may be added that they maintain their bent shape during the summer.

Fig. 1. — Typical winter landscape of Cantal region.

1. *Importance of hoar-frost deposits.*

During the time the lines were under observation, hoar-frost sleeves were recorded round conductor cables of 35 mm² section; these sleeves measured 14 cm on the biggest diameter of the section, the section is generally elongated in shape with the conductor located in the upper part, if the ice has formed when there was no wind.

If a wind of average velocity was blowing, the section takes the shape of a flag, the conductor being, more or less, the flag staff.

In many places, diameters of hoar frost of 7 to 8 cm on wires of 4 mm diameter have been noted and diameters of 11 and 13 cm and, even, 18 and 24 cm have been attained, up till 1933, on rural lines, the load exceeding 12 kg per lineal metre. In the winter of 1934/1935 (on the Monts de la Margeride) a load of 20 kg per lineal metre was noted on a low-voltage line built of copper-steel cable of 18 mm² sections; the diameter of the ice deposit,

Fig. 2. — Line covered with hoar frost.

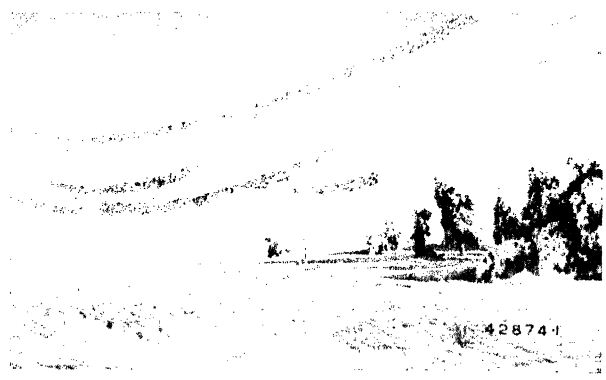


Fig. 4. — Telephone lines partly covered with hoar frost.

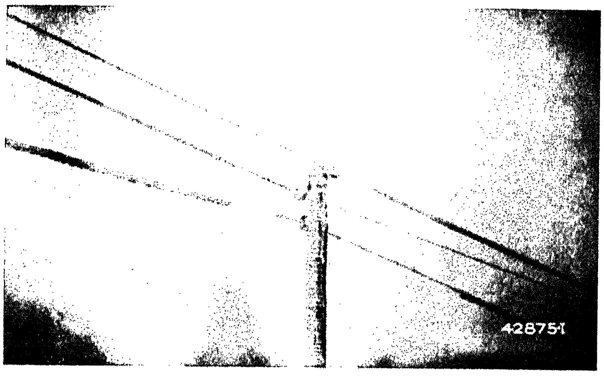


Fig. 5. Ice-coated high-voltage line.

which was a perfectly regular cylinder, was 40 cm (Figs. 2 and 3).

2. *Formation of hoar frost. Action of wind, temperature.*

Hoar frost generally forms when the humidity of the air is high:— wooded country, valleys, neighbourhood of lakes, marshes. The intensity of the hoar-frost formation and its frequency of occurrence depend on the altitude and the direction of the winds in the region.

The assumption generally adopted was that hoar frost forms in calm weather at temperatures near 0^0 C (— 1 to + 3^0 C). It was, also, assumed that a wind of 10 kg/m^2 did not allow hoar-frost formation of more than three diameters while a wind of 40 kg/m^2 did not allow formations above two diameters.

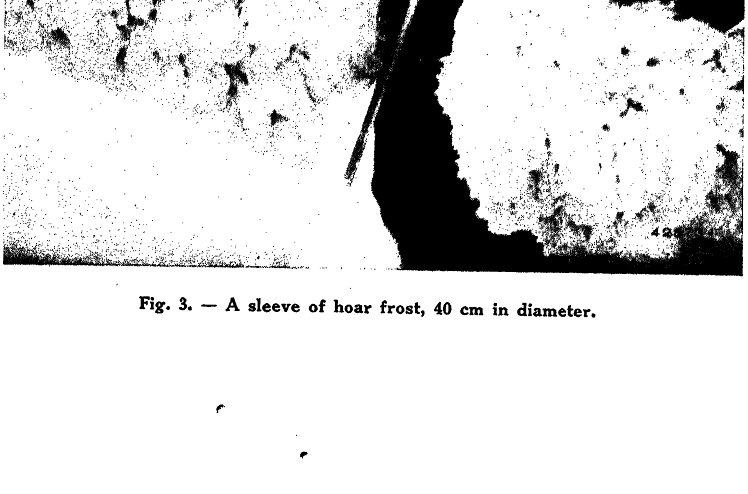


Fig. 3. — A sleeve of hoar frost, 40 cm in diameter.

In the course of the investigation and contrary to this hypothesis, it was noted that considerable hoar-frost formations were possible under fairly high winds and in very cold weather (temperatures varying between — 7 to —25^0 C).

Ice particles agglomerate very fast under wind pressure; it would seem that the wind eddies caused by topographical inequalities aggravate hoar-frost formation in regions where the velocity of the air is highest.

The following phenomena was noted:—

On two neighbouring lines, one for power transmission and one for tele-

phone and telegraph service, the high-voltage conductors, further from the ground than the telephone lines, were loaded by a 12-cm sleeve of ice while the telephone lines were surrounded by 23 cm of hoar frost (excess-load of 12 kg per lineal metre) (Figs. 4 and 5).

The hoar-frost deposits on the poles are, generally, accentuated towards the base the silhouette being that shown in Figs. 6 and 7 (a—b—c).

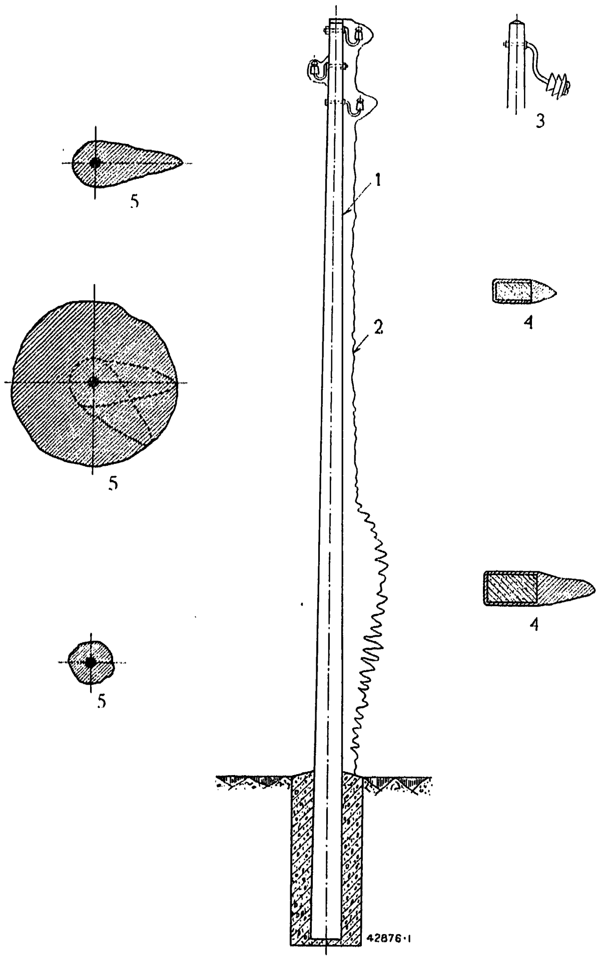


Fig. 6. — Outline drawing of a pole covered with hoar frost. Sections of hoar-frost coating on poles and conductors and insulator bolts deformed by excess loading.

1. Pole.
2. Hoar-frost formation.
3. Distorted insulator support.
4. Section of mast.
5. Hoar-frost formation on conductor.

Fig. 7a. — Pole with hoar-frost formation.

Such considerable hoar-frost deposits are due to the condensing of thick fogs during several consecutive days, at altitudes of over 700 metres.

Sometimes, however, the formation is very rapid. It has, often, been noted in the Dômes mountains, chiefly on the Puy de Dôme that an ice sleeve of 30 cm diameter forms round a 4 mm wire, in less than 30 minutes (altitude 1300 m) (Figs. 8, 9, 10, 11).

If the formation of the hoar-frost deposit takes place when there is no wind, it may happen that gusts of air then blow on the lines after the said formation and before the hoar frost has begun to melt; the resulting overload of the conductors is then considerable.

The direction of the lines also plays an important part. It has been noted that, in general, break-

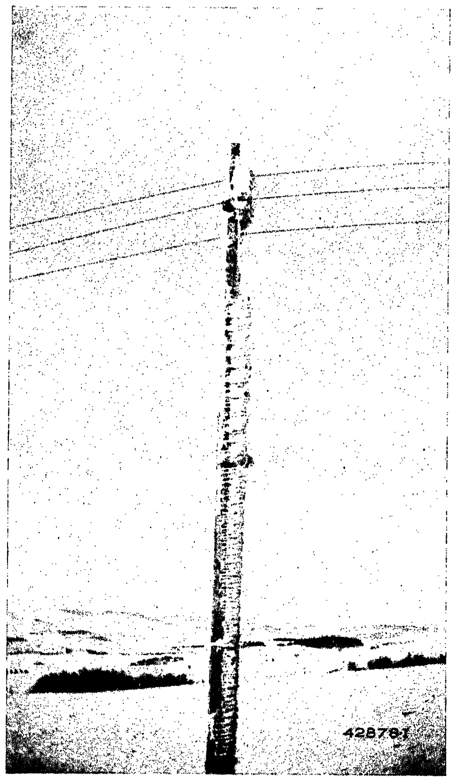


Fig. 7b. — Pole with hoar-frost formation.

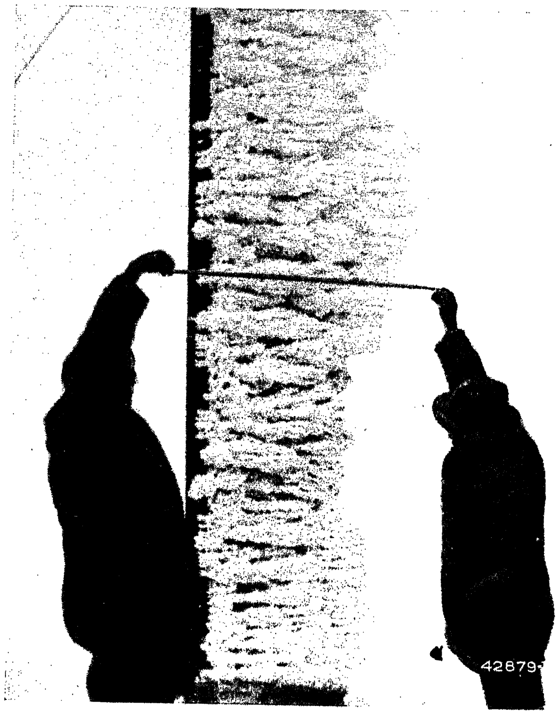


Fig. 7c. — Detail of hoar-frost formation on pole.

downs occur on all the lines running east to west when the direction of the winds was, mainly, north to south.

3. *Density of the hoar frost.*

The density of the hoar frost varies very much, it is often low, 0·2 to 0·3 but it sometimes attains the density of ice. Density varies according to years and localities. At places where accidents occur, the hoar frost is generally compact and of the hardness of ice. In this case, it adheres to the conductor (wire or cable). The texture of the hoar frost is cristaline (see Figs. 2 and 3).

4. *Influence of the nature and diameter of the conductor.*

The diameter of the hoar-frost deposit is not proportional to that of the conductor, whether wire or cable. Lines in hilly country in the region under consideration have the following characteristics:—

60-kV line:— hard-copper wire of 8 mm diameter.
40-kV lines: hard-copper cable of 35 mm^2 (19 wires).
Earth wire of galvanized steel, 25 and 35 mm^2.
Rupturing strength 70 to 90 kg/mm^2.
20-kV lines:— hard-copper wire of 8 mm diameter.
Rural lines:— hard-copper, 4 and 5 mm.
Silicon bronze 3·4 and 5 mm.
Copper-steel cable of 18 and 22 mm^2.

The form of the deposit seems to vary with electric voltage of the conductor. The hoar-frost aigrettes are bigger for high than for low voltages.

Fig. 8. — Line destroyed by hoar-frost.

Fig. 9. — Rupture of wooden pole and, beside it, remains of concrete mast destroyed a year before.

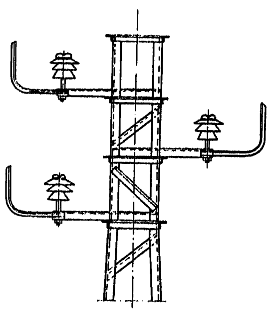
Fig. 10. — Broken wooden mast.

5. *Distribution of the hoar frost.*

This is often uneven as Figs. 4 and 12 shows.

6. *Phenomena recorded.*

Conductors.—Conductor breakages caused by the following three types of fatigue have been noted:— traction, torsion (for wires) repeated vibration.



The enormous overload causes permanent elongation and then rupture.

The section of the hoar-frost deposit towards the fixed points is elongated, when formation takes place under the influence of strong wind, the bigger axis being horizontal. The weight of the hoar frost, the mass of which is excentrically located as regards the conductor, produces deformation by torsion in the case of lines with rigid support points. This torsion is of such magnitude that the section of the hoar frost at the middle of the span is a regular circle the diameter of which corresponds to the bigger diameter on the right of the point of fixation.

Fig. 11. — Concrete pole broken by forces acting perpendicularly to the direction of the line.

Figs. 2 and 3 correspond to a low-voltage line with flexible suspension. The hoar-frost cylinder is perfectly regular all along the line (40 cm diameter). The hoar frost formed under average wind strength, but the movable points of suspension prevented torsion as the conductors could rotate round their axis.

The continuous vibration of conductors ondulating in the sense of the line length causes supplimentary fatigue towards the suspension points. The fastenings of the conductors distend, the wire and

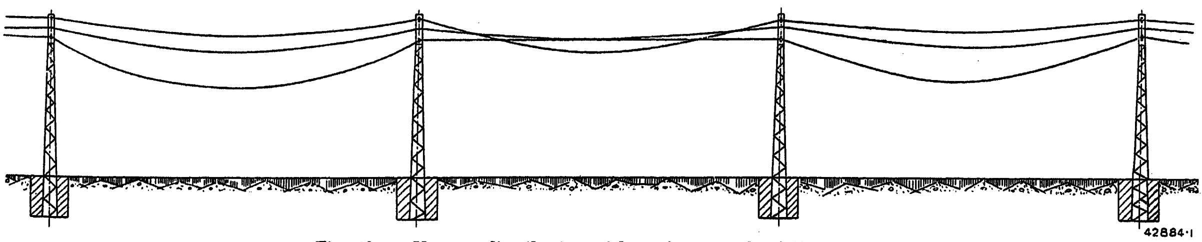


Fig. 12. — Uneven distribution of hoar frost on the different lines.

the fastening wear together under the influence of the vibrating torsion phenomena.

Insulator arms.—The swan-neck insulator arms are deformed, carrying the insulators with them, which latter are then turned quite over.

Supports. Metal towers.—A line made of copper cable of 35 mm^2 with an earth wire of steel of the same section, situated near the Monts-Doré at 1100 m altitude, showed towers broken on several occasions and laid completely on the ground (span 70 m).

Rural lines.

a) *On wooden poles.* — Generally the poles break somewhere between the ground and 2 to 3 metres above it (Figs. 9—10).

b) *On concrete poles.* — These poles break on account of a rupture of the conductors; only a few of them break under a force perpendicular to the direction of the line (Fig. 11).

The pole rarely breaks on the ground level and the most dangerous section is at a joint in the metallic armature of the reinforced concrete, at half of and at $^2/_3$ of the length from the base.

The rupture of a single conductor produces excessive torsional fatigue. The position of some poles after breakage seems to show that rupture was due to a combined torsion effect followed by a bending one.

The rupture of conductors causes the line poles to break up to the first anchoring tower or angle support.

Brackets.—Many of these were torn out or bent, on the low-voltage lines.

Line construction. — Since 1928, the construction of rural lines subject to hoar-frost deposits has seen strengthened, year by year, as the magnitude of the loads carried was realized and the number of breakdowns noted.

It would seem that rigid structures with the heavy and expensive work inherent thereto should be given up in favour of a flexible suspension of lines. In the year 1935, the Cie Hydroélectrique d'Auvergne built a whole mountain network with suspended fittings so designed that the following faults were eliminated:

(a) Excess fatigue of pole due to torsion.

(b) Continuous fatigue of conductors due to torsional vibrations.

(c) Rupture of supports following that of conductors.

The construction of this network being of recent date, it is premature to pronounce judgment on the design, which up to date, has given satisfaction.

The solidity of the conductors has been strengthened by choosing cables with steel cores (copper, steel). For certain lines, it is preferable to use galvanized steel cables of high tensile strength (180 kg/mm^2) if there is no electrical argument against so doing.

(MS 516) *(Mo.)*

THE EQUIPMENT OF LOAD-DISPATCHING STATIONS FOR THE SUPPLY SYSTEMS OF BIG TOWNS.

Decimal index 621. 316. 267.

I. OBJECT OF CENTRALIZING CONTROL.

Within recent years, many big electrical power-supply concerns and especially those supplying big towns, have centralized the control of their systems. From the point of view of organization, this means that a certain group of service operations, which formerly belonged to the independent operating fields of individual power and switching stations, are now entrusted to a new control post, common to all. The liberty of action of the various individual stations was limited by this innovation, as, now, their own control rooms were called on to carry out, solely, switching operations ordered by, or consented to by, the load-dispatching station. The real cause of this modification of service organization is to be sought in the full recognition of the fact that switching operations carried out at a given point on an interlinked system react on the other service points of the system and that the effect thereof cannot be estimated unless the entire operating situation is grasped.

At first, it was considered sufficient, to transmit by telephone to the various central control posts all the data they required for giving out switching and regulating orders. Very soon, however, difficulties were encountered due to retarded reception of important messages which led to faulty decisions being reached and wrong switching orders being given out. For this reason, the solution generally adopted, to-day, is to equip the central control posts

with special technical facilities for automatic remote metering, remote signalling and remote control. However this may be, existing plants still show little uniformity in their equipment. The direct cause of the putting in of a load-dispatching station was not always the same. In equipping the load-dispatching station, the greater importance was sometimes attached to remote metering devices while, in others, more weight was laid on remote signalling of the switching positions. To-day, there is still no unanimity as to which of the remote meterings and which of the remote signallings are the most important ones for given local-service conditions. The following paragraphs are devoted to the investigation of what considerations should be given precedence and what available experience can be made use of in the designing of these stations.

II. THE CHOICE OF EQUIPMENT.

The decision as to what equipment should be chosen is not limited to the choice of the most suitable designs but is chiefly dictated by the scope of the plant.

In determining what organs it is essential to equip for remote metering, signalling and controlling, the obstacle of too great an outlay on the technical equipment of the load dispatcher often play a part. As opposed to this is the fact that the avoidance of one single major case of trouble on the system and the consequent break down of the supply of industrial plants may cost as much as the outlay for the whole equipment of the central load-dispatching station. Further, there are calculations available, made for a few big power distribution concerns, which show that the avoidance of power losses, thanks to proper current distribution in the system, is sufficient to justify putting a bigger sum into the equipment of the load-dispatching station. Above all, it should be noted that it is not necessary that all the devices should be put in at one and the same time. The most important requirements can be fulfilled, to begin with, this, of course, while keeping in view the final stage of development and all the possibilities of expansion of the existing system.

The load dispatcher has to fulfil a double duty. With regard to the economic interests of the total service, it has to determine what number of machines, transformers and lines are to work at a given time. To safeguard the service, it must take all measures to avoid break downs and, if such do occur, to see that the trouble is expediously cleared. The equipment of the load dispatcher has to make available to the operator all the data which is necessary to fulfil the above functions. Among the means available which have proved their reliability in service, mention should be made of the following ones:—

Equipment for remote metering
  to transmit any measured values over the smallest possible number of pilot leads.

Equipment for remote signalling
  to indicate the positions of breakers and to give alarm signals.

Equipment for remote switching
  to control breakers, to send switching orders to distant stations, to regulate the system.

Mimic diagrams with record of switching positions
  to increase supervision of the whole system.

Recording devices
  to keep a record of all operations for subsequent control.

These different components which make up the complete equipment are described in the following paragraphs.

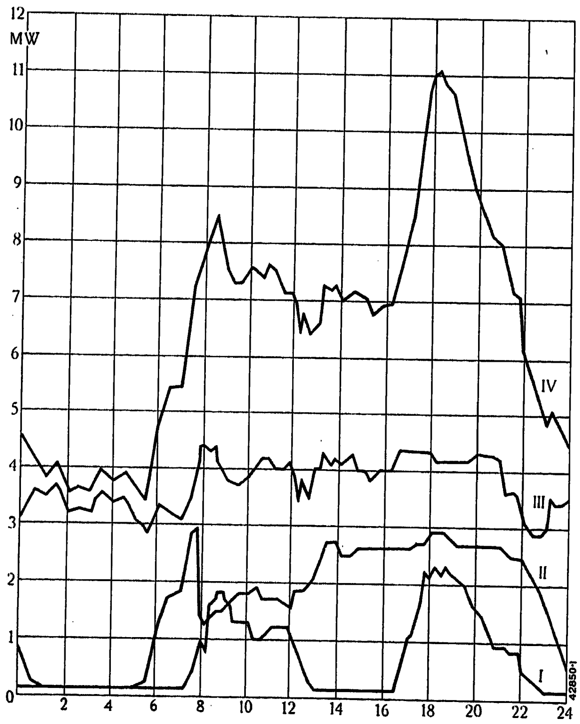


Fig. 1. — Characteristic day diagram for the power supply of a big city, with a centralized supervising station.

I. Power supplied from two steam power stations belonging to the system.

II. and III. Power supplied from a distance from two neighbouring hydro-electric companies.

IV. Total power.

The day curve of the loads utilized shows the rapid adaptation to requirements by the supervising station, there being no sharp separation between basic load and the covering of peak requirements.

(a) *Remote metering.*

As regards the technique of metering supervision, there is a big difference between overhead systems and big-town cable systems. In the latter, the question of transmission capacity of the lines, that is of the temperature rise of the cables is of primary importance: therefore, the current strengths must be remote-measured, in the first place. To do so, it suffices to supervise each line which serves to feed separate areas supplied or which links up the power stations and the substations. The supervision of single distribution lines can be left to the care of the various switching stations on the system.

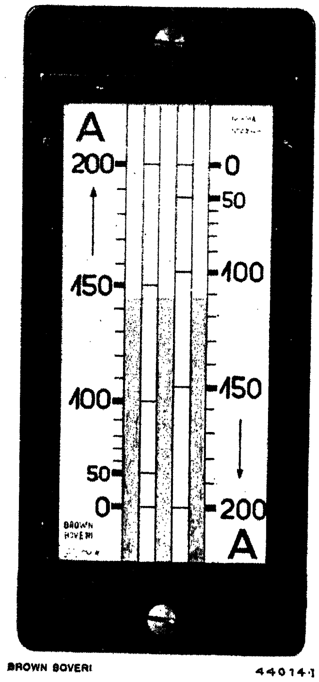


Fig. 2. — Remote-measurement receiving apparatus of the luminous type to supervise parallel cables subjected to reversal of sense of power flow.

Those lines which form parts of the ring system are of special importance and the reason for this is easy to grasp:— if a separate single feeder cable fails, the consumers connected thereto are deprived of current and this means that the load on the rest of the system is lightened by so much; if, however, a length of line in the ring is cut out, the consumers get their power by another branch which, then, carries a bigger load. The original break down can, thus, be the cause of further automatic breaker trippings. When this takes place, the loads go up by bounds, so that remote supervision of ring lines of the kind in question must be warmly advocated. As a reversal of the sense of power flow can take place in the various lengths of line, it does not suffice to measure the strength of the current alone. For this reason, Brown Boveri uses, for loading measurements, current-indicating devices with double scales which give the sense of power flow as well as the strength of the current. In this measurement the indication of sense of flow is arrived at by placing a reverse-power relay at each point of measurement.

The conditions are fundamentally different in an overhead system. The transmission capacity of overhead lines is, in general, not determined by the temperature rise but by the stability of parallel operation. Thus, supervision of short overhead lines can be entirely dispensed with. Only long overhead lines with power generators at both ends call for supervision; in this case not by current indications but by measurement of the active and reactive load with indication of the sense of flow for both components.

The next in importance is the technique of measurements as applied to power stations, transformer stations, and switching stations. From the point of view of the total operating system, each station on the system is a self-contained unit and the load dispatcher has not got to know how the total load is distributed on the individual machines or transformers in the station. For the load dispatcher the only factors of interest are the total load being delivered and the machine power available in the station, i.e. the spare power still available. A remote

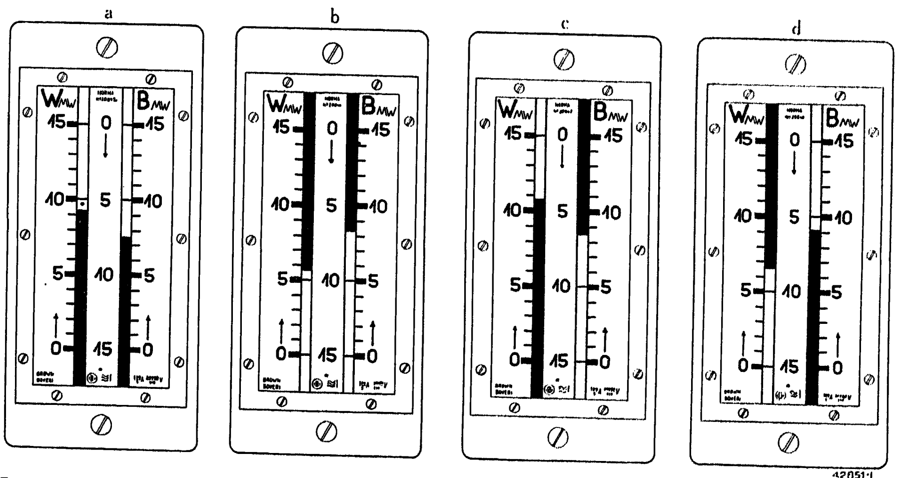


Fig. 3. — Characteristic scale arrangement of a luminous double wattmeter for active and reactive load.

	Phase angle		Phase angle
a. Delivery of active and reactive load	0— 90°.	c. Active power delivered and reactive power tapped	270-360°.
b. Active and reactive load tapped	180—270°.	d. Active power tapped and reactive power delivered	90-180°.

metering in which the individual loads of machines or transformers are added together, on the site of the station and transmitted to the load dispatcher, is sufficient. This measurement is completed, advantageously, by measurement of the bus-bar voltage of all the stations on the system.

In the load dispatcher stations built up till now, only the active load, but not the reactive one, was taken into account; this limitation does not seem advisable. Remote metering of the load is the basis used by the engineer supervising the service in order to permit him to determine the distribution of the load on the different generating points, and it is, thus, the basis of economic power generation. This, however, refers to reactive as well as to active load. Reactive load causes very accentuated additional heat losses due to bigger currents in machines, transformers and lines, which must be made good under the form of active load and which amount to several

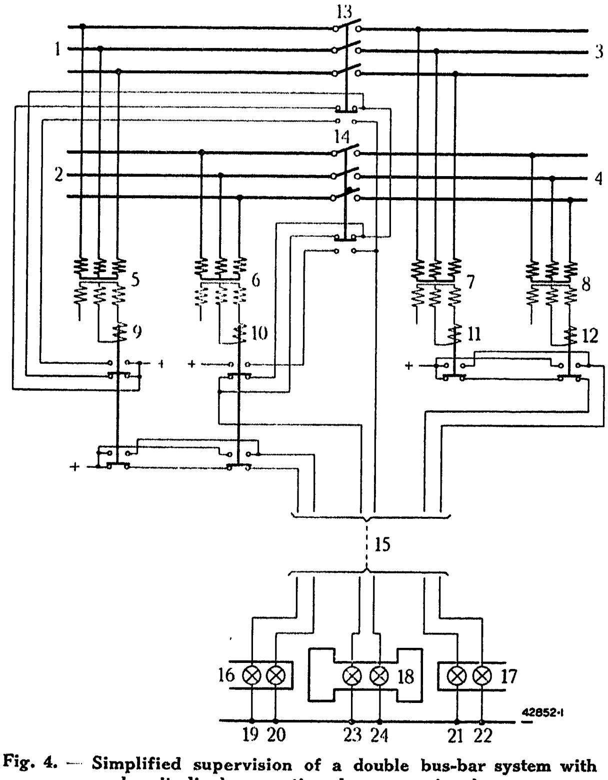


Fig. 4. — Simplified supervision of a double bus-bar system with longitudinal separation, by group signal.

1— 4. Three-phase bus-bars.
5— 8. Voltage transformers.
9—12. Voltage relays.
13—14. Disconnecting switches for longitudinal coupling of the bus-bars.
15. Remote transmission equipment.
16—18. Switching indications in the light diagram of the control post.
16. Common switching indication for the bus-bars 1 and 2.
17. Common switching indication for the bus-bars 3 and 4.
18. Common switching indication for the coupling breakers 13, 14.
19—21. Signal lamps for no-voltage condition.
20—22. Signal lamps for "alive" condition.
23. Signal lamp for bus-bar separation.
24. Signal lamp for bus-bar coupling.

per cent of the total current. An improvement of the efficiency by a few thousandth parts suffices to compensate, within a few months, for the cost of wattless-power metering.

Remote metering of the frequency is not, generally, necessary, because, under ordinary conditions, the separate power stations working on the system remain in parallel and the load dispatcher itself gets its voltage from the same system. Therefore, a frequency meter, connected to the house system of the load dispatcher, suffices. In systems with regulation of frequency for the operation of synchronized clocks, it is customary to place in the station a reference clock with a double system of hands, one being driven from the electric system and the other from a standard astronomically-regulated clock.

Mention must also be made of the so-termed measurements on enquiry. Especially in American and British practice, plants are built which have a common metering line for several measurement posts, and a single indicating device in the control room, which can be switched over. In the interests of reliable service, plants of this kind cannot be recommended. They incorporate a factor of danger, in so far as the sudden growth of any given value may not be signalled immediately to the service engineer and valuable time may be lost before counter measures are taken.

The choice of the method of remote metering depends, in the first place, on the kind of measurement leads used. There is an impulse process and an intensity process. In the first, the magnitude measured at the emitting point is transformed into a series of impulses, and, as a rule, the number of impulses per unit of time serves as a measure of the measured magnitude. The impulses can be transmitted by any kind of current. This process has the advantage that fluctuations in the value of the resistance and insulation of the pilot leads produce no error in measurement. On the other hand, the intensity processes are simpler and cheaper. They transform the magnitude measured at the point of emission into a D. C. current proportional to the said magnitude which is measured at the receiving end by a simple moving-coil instrument. Errors in metering due to fluctuating values of resistance and insulation can be compensated for, to a great extent, by series resistances at the emitting point. Practice has shown that both systems are very satisfactory, indeed, when properly applied. If the pilot leads are very long, or if they are in the form of overhead

lines, the impulse system alone can be considered. If the distance is of a few kilometres, only, and if there are cables available, as is nearly always the case in big towns, an intensity system suffices entirely and must be considered as the more economical. For the remote metering of rapid phenomena such as the recording of surges, the intensity system is the only one which can be used, in the present stage of technical development.

(b) *Remote signalling.*

The same considerations as for remote metering are valid when choosing what parts of the system should be equipped with remote signalling. Supervision of every breaker on the system is, generally, neither possible nor useful. Here, again, the rule applies that only those parts of the system which are important for maintenance of the total service should be subjected to central supervision; by which is meant those parts, defects on which produce repercussions on the whole system. As a rule, big distribution systems are composed of one or several rings of high-voltage lines. These feed medium or low-voltage systems, which are, practically, independent of one another. The central load-dispatching station will, therefore, limit itself to supervision of the stations and lines belonging to the high-voltage system. When individual parts of the medium-voltage system are so extensive or so important as to make supervision from a central station desirable, this duty should not fall on the dispatching station of the entire system; it is, obviously, more suitable that these parts of the system be supervised by load dispatching stations of their own. On the other hand, the fundamental principle must be applied for the central load-dispatching station, that the remote signalling of the parts of the system supervised by the said station be complete. If, now, a decision has been reached as to what parts are those which require remote signalling, then it is logical that all lines which supply power to, or tap power from the said parts must be remotely supervised. An attempt to omit to supervise any branch line of secondary importance belonging to a bus-bar system which is, itself, remotely supervised in other respects may have very serious consequences at some later date.

When load dispatching stations are being designed, a question which comes up, nearly always, is

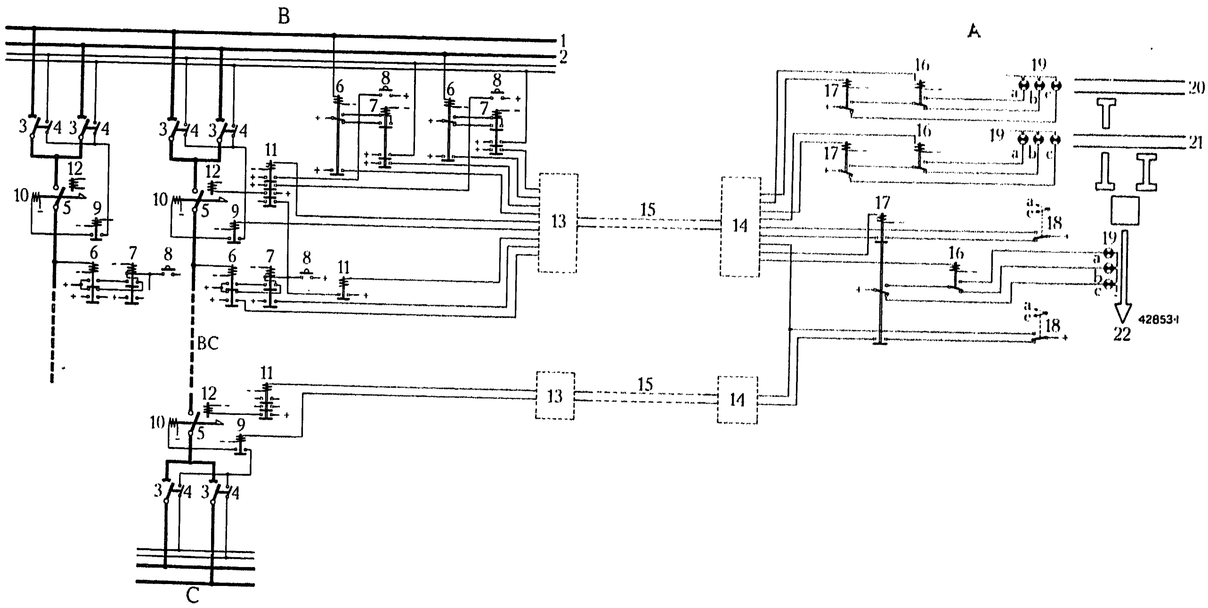


Fig. 5. — Example of a system of connections with interlocking feature, for conditional reclosing of parts of the plant under no-voltage.

A. Control post.
B, C. Controlled service posts.
1— 2. Three-phase bus-bar system of service post B.
3. Bus-bar disconnecting switch.
4. Auxiliary contacts on disconnecting switch drives.
5. Line breaker.
6. Voltage relay for the bus-bar.
7. Releasing relay allowing remote reclosing from the control post.
8. Push-button switch for releasing the locking device preventing reclosing, after trouble.
9. Control relay for remote closing of line breaker 5.
10. Closing magnet of line breaker 5.
11. Control relay for remote tripping of line breaker 5.
12. Tripping magnet of line breaker 5.
13—14. Selective gear for remote control and remote signalling.
15. Remote-control line.
16. Signal-reception relay for voltage condition.
17. Signal-reception relay for interlocked condition.
18. Control switch for line breaker 5 of distance lines B and C.
19. Signal lamps in light diagram for switching signals 20, 21 and 22.
19a. Signal lamp for "voltage" condition.
19b. Signal lamp for "ready for closing" condition.
19c. Signal lamp for "interlocked" condition.
20—21. Switching signals in light diagram for bus-bar systems 1 and 2.
22. Switching signals in light diagram for lines B and C.

whether remote-position signalling for the power breakers of the system alone suffices or whether the disconnecting switches should also be similarly equipped. It is, of course, obvious that the engineer supervising the system must be informed of the position of the disconnecting switches. Therefore, at the least, he must have available so-called marking switches which are moved according to telephone messages and which serve as reminders. As in systems having a central supervising station, the rule must hold good that switching operations in supervised stations must only be carried out with the consent of, or at the order of, the load dispatcher, these marking switches are a good substitute for automatic position signalling. As opposed thereto, it must be remembered that position indications given verbally are liable to occasional errors or that, after the telephonic indication has been given, the operator, in a hurry, forgets to alter the marking switch, which may have serious consequences. Above all, however, verbal indications by telephone take up much time and occupy the line which might happen to be wanted urgently for important information, for switching orders or to clear the cause of some trouble. As a fundamental rule, it may be laid down that automatic remote-position signalling of the disconnecting switches, as well, is always advisable when these are used to carry out ordinary service switching operations. If the stations have only got a single bus-bar system, remote supervision of the disconnecting switches can, certainly, be done without. Further, disconnecting switches which are not used for ordinary switching operations and only for isolating during overhaulages do not require any remote-signalling equipment. On the other hand, the disconnecting switches for changing bus-bars must always have remote-signalling equipment and the supplementary cost thereof does not amount to much.

The fact that every plant contains disconnecting switches for important service switchings and others for secondary objects leads to equipping only the first for automatic supervision and to using hand-operated marking switches for the other ones. However, an arrangement of this kind is in glaring opposition to the demand for uniform organization of service. The operators of the separate stations cannot be expected to always remember if a telephone message of a switching operation has to be sent in to the load dispatcher or if it is done automatically. If some disconnecting switches are given automatic remote-signalling equipment, then, in some way, all the others must be included, as a natural consequence.

However it is not necessary to provide every switch with its own remote signal, the principle of group signalling can be used.

If a circuit breaker and a disconnecting switch are in series on a length of line, both can be considered as forming one switching-apparatus set, that is to say one common signal is given for the closed position of both apparatus and another for the open position when one of the two apparatus is open. Combination signals of this kind are easily made up by series or parallel connection of the signalling contacts and allow of considerable saving in the outlay for the remote-signalling gear.

When the systems contain choke coils with taps for compensating earth currents, the tapping switches of the said choke coils must be included in the apparatus supervised.

Further, automatic remote-signalling of the number of machine sets at work is very useful, because the elimination of a machine set may be of great importance to the service. But it is not necessary to have remote signalling to tell whether a machine although cut out is ready to be put into service again. To this end, marking switches by means of which service conditions can be recorded from telephone messages can be used. If steam power stations are under consideration, the considerations just stated are valid for the boilers as well as for the machine units.

The choice of the best transmission system for remote signalling is easy. In general, a multiple transmission is used, in which all signals from a station are transmitted by a single common remote circuit. Direct transmission with one line per signal is only economical in special cases. The equipments for multiple transmission have already been considerably developed. While costing little, they are very efficient. The following demands are made on modern signal transmission systems:—

(1) The equipments must be so designed that no erroneous signals are given and this even when the equipment itself or the signal transmission line is damaged, or if transitory disturbances occur in the installation such as conductor breakages, break down of insulation or outside influences due to induction etc. If a fault occurs on the signal transmission, it must, if possible, be indicated clearly with automatic indication of the point affected. Under no conditions should a failure of the equipment to

work result in neither a remote signal nor a trouble signal being transmitted to the receiving post.

(2) The total remote transmission of all signals including auto-supervision of the transmission processes must take place entirely automatically. If several remote signals await recording they must come through one after the other without intervention of the operator.

(3) When several signals are sent nearly simultaneously the first signal process started must be the one to come through first. The selectivity in the order of transmission precedence must be of a higher order than the selectivity of the relays protecting the system. Only under this condition is it possible to detect in the load dispatcher station what the cause of accidental cases of trouble is on the system. When two or more signals await transmission at exactly the same moment, the transmission thereof should take place automatically in the sequence of their importance. The degree of selectivity of modern remote-signalling equipments attains 0·2 to 0·3 seconds. This shows the enormous advantage of automatic remote signalling when compared to a system based on messages transmitted by telephone.

(4) The design must be such that low currents suffice for remote transmission of the signals, as it is impossible, for obvious reasons of economy, to lay down heavy pilot leads. In the electrical systems of big towns, separate couples of conductors of telephone cables are used, practically, everywhere, these being hired from the postal authorities for the purpose. To transmit signals and measurements over long lengths of overhead transmission lines high-frequency telegraphy along the main line and, often, a low-current aerial cable hung on the earth wire are used.

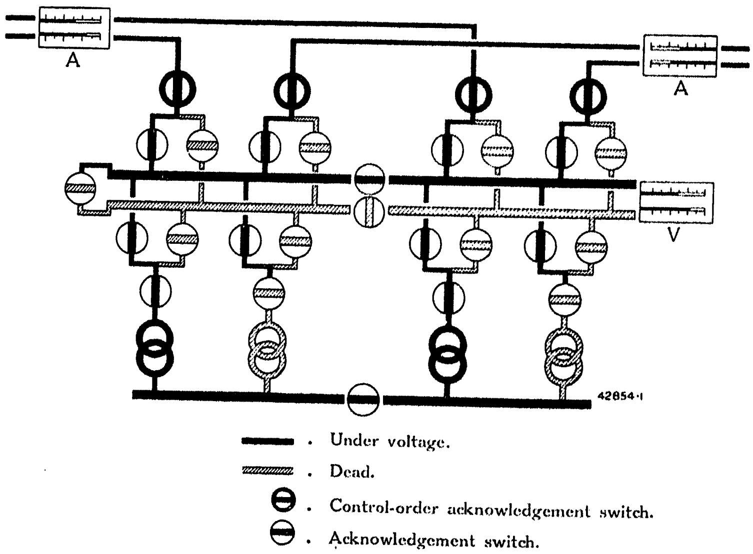


Fig. 6. — Representation of a transformer station in a light diagram, with return signals and acknowledgement signals combined.

(c) *Remote control, remote transmission of orders and remote regulation of the system.*

Most of the load-dispatcher stations put up, so far, have automatic devices for remote metering and remote signalling but use the telephone for giving switching and regulating orders. Thus, the remote supervision exercised by the load dispatcher station on the different stations is only semi-automatic. This limitation is not a matter of expense, because the additional cost of direct control from the load dispatcher station is very slight as compared to what is spent for the metering and signalling equipment. Experience shows, however, that there is a certain hesitation manifest in technical circles when it comes to a question of the remote control of big power stations and switching stations. There is justification for the argument that the official in the load dispatching station cannot possibly have as clear an idea of conditions in the remote station as the operators in the station itself, and that mistakes may be made occasionally, because of this. On the other hand, there is a real need of remote control; many serious cases of trouble could have been avoided by the prompt interventions of a central supervising station. A classic example of this is the service trouble on one of the big European overhead systems in the summer of 1934. This began with the failure of one overhead line, which caused other parts of the system to be overloaded. Although the system stood up to this overload for 19 minutes and although there was a load-dispatching station with the requisite remote metering and remote signalling equipment, nothing could be done to prevent the whole system going to pieces and leaving big tracts of country without power for over an hour. In the reports on this case of trouble, it is specifically stated that the trouble could probably have been prevented if the load dispatcher had possessed the means of prompt intervention. Mention should also be made of the very conclusive report of the

Belgian National Committee made by Stalin at the Conférence des Grands Réseaux in the year 1933. In this report the experiences made with a system are reported on which first worked without auxiliary help and then with central supervision and, finally, also with central control. This was an overhead system subject to fairly frequent trouble. The record of cases of trouble before the load-dispatcher station was put in showed an average duration of current failure of half an hour. After remote metering and remote signalling had been added this average duration fell to 14 minutes and down to 2 $^1/_2$ minutes after remote control was put in.

The present situation can be so summed up as follows:— the need of direct remote control from a load-dispatching station is fully as great as the reasons which can be justifiably opposed to the innovation.

An attempt at, at least, a partial solution of the problem has been made by putting automatic transmission of orders to be carried out in the place of transmission of the control operations themselves. This measure has been successful in so far that the number of telephone communications are considerably reduced, which gives more freedom to the operator and leaves the telephone line free for other communications. The transmission of orders as compared to that of control operations has the indisputable advantage that the operators of the supervised station are not eliminated and, being conversant with the conditions in their own station, can exercise a secondary control on the advisability of any operation ordered. On the other hand, the object proper of remote control, i. e. acceleration of switching and regulating processes, is not entirely satisfied.

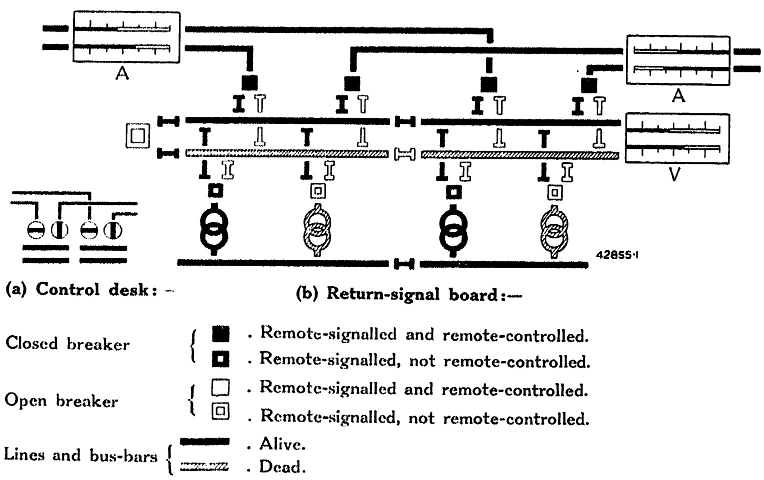


Fig. 7. — Representation of a transformer station, as in Fig. 6, in a light diagram for return signals and with separate desk for control.

The operating difficulty met with in direct central control is that the two following and contrary conditions have to be satisfied:— on the one hand the elimination of the local operators is desirable in the interest of rapid control; on the other hand, the collaboration of the said operators is valuable for supervising the switching operations. However, the problem set can be solved, because the contrary conditions laid down do not coincide in time and place. The supervision of a switching operation intended is only necessary in the case of reclosing on a live section which has been defective. The putting in or the switching-over of sound sections of the plant can be carried out directly that is without intervention of the local operators. A central control station can, therefore, be used perfectly when an interlock is provided which makes reclosing by the central control of a part which has been cut, due to an automatic breaker tripping (lines, bus-bars, etc.), dependent on a previous opening of the interlock by the station operators. The shift of the station implicated has got to test, after each automatic trip, whether reclosing is allowable and this independently of whether the load dispatcher station desires a reclosing or not.

This arrangement proposed, which may be designated as a conditional load-dispatcher station control, should meet the demands of practice satisfactorily. Hesitation as regards possible service errors due to ignorance of local conditions now vanish, because reclosing is, now, only possible if the operators in the station implicated have freed the interlock. The object aimed at of rapid carrying out of all switching operations is, now, fully attained, because, under normal conditions, all breakers of the parts of the system supervised are free to be operated. Even when the interlocking is effective, the switching time is reduced to a minimum because the investigation as to the admissibility of a reclosing, carried out by the local operators, takes place immediately after the trip and not only after a possible switching order has been emitted by the load dispatcher. Of course, the operators in the remote-controlled station have, always, the possibility of cutting out a breaker, in an emergency, in which case it is impossible for the load dispatcher to reclose the breaker without knowledge of the said operators.

It is not absolutely necessary that the position of the blocking device of the centrally-controlled breaker be remote-signalled to the load dispatcher. A simple local interlocking in the remote-controlled station saves the number of remote signals, but has the disadvantage that the load dispatcher does not know what switching operations can be carried out. There is also no control whatever on whether the operators in the system stations always investigate every case of trouble. For this reason, remote-signalling that a breaker which has been tripped is now free to be reclosed should not be dispensed with. The extra cost of this additional apparatus is very slight and amounts to only 3 to 4% of the load dispatcher total equipment. A cheaper solution is an automatic interlocking in the load-dispatching station which can be freed by the service supervising engineer himself as a result of a telephone call. Only

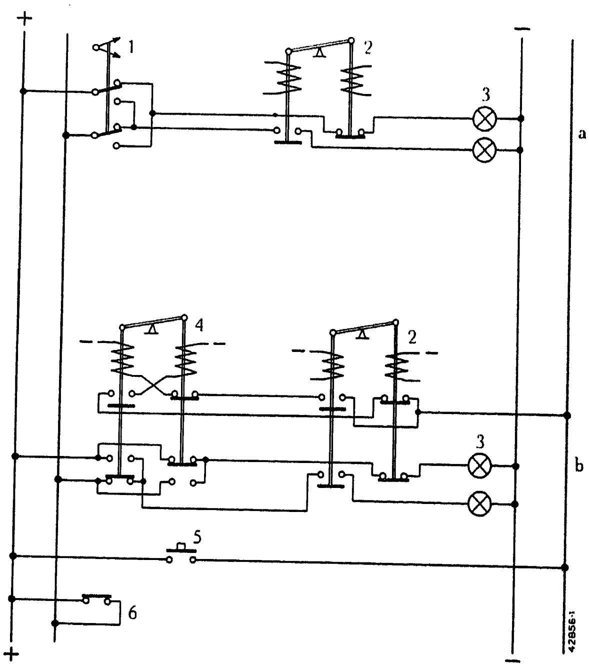


Fig. 8. — Acknowledgement connections for change-of-condition signs by pulsating light signals.

1. Single switch for acknowledgement.
2. Remote-controlled tipping relay for signalling condition.
3. Signal lamps for "out" and "in".
4. Double relay for acknowledgement by a common switch.
5. Common push-button switch for acknowledgement.
6. Pulsating contact.

experience shows which arrangement should be given preference.

The guiding principles laid down in the preceeding paragraphs for the control of breakers, are valid, with all due modifications, for carrying out regulating operations. The necessity for carrying out regulating operations from the central control post is, however, not so absolute. The most important part is played by the problem of synchronization in the case of linking up supply transmission lines when the latter do not terminate at some power station belonging to the complete system. In this case, synchronization must be carried out in some switching station from which the frequency cannot be influenced and the switching operator must wait for a considerable length of time before he can execute the switching order, in cases where the frequencies are maintained exactly. As, especially in cases of trouble, it is important to be able to switch in spare sources of power or to resynchronize generators which have fallen out of step, it may appear advantageous to be able to influence the frequency of the system from the load dispatching station and to be able to execute from there paralleling operations. This is not possible, so far, in the load-dispatching stations built up till now.

As regards the arrangements for the remote transmission of control signals, the designs used are similar to, or identical with, those employed for remote signalling. As special designs, mention should be made of the devices for the automatic maintenance of machine loads adjusted to and for regulation according to a time table drawn up in advance. A description of this apparatus would, however, go beyond the scope of this article.

(d) *Devices to facilitate supervision in the load-dispatching station.*

The number of meterings and of signals in the load-dispatching station is always so big that special measures have to be taken to facilitate general supervision of the operating conditions. For this purpose, a return-signal and measuring mimic board is used which, nearly always, takes the form of a light diagram. The most important feature of this board is the placing of the metering, signalling and controlling devices in their proper places on the diagram. Boards on which the instruments are simply mounted in a row without any visible diagrammatic connections, are only found in old plants and can now be considered as obsolete. A special advantage of the light diagrams is the indication of the momentary voltage conditions pertaining in all parts of the system. For this, it is not necessary to use special remote-signalling devices in order to reveal voltage at different points on the system, the said voltage is automatically deduced from the remote-signalled position of the breakers. Another advantage is the helpful way in which changes in electrical conditions are indicated. When changes in the breaker and in the voltage situation take place, pulsating light signals indicate what parts of the system are involved. In the same way, before a switching operation is carried out, or before an order impulse is sent out, it is possible

to find out in advance what the results thereof is going to be, this simply by moving a testing switch which causes pulsating lights to show what the resulting conditions will be.

There are two different designs of light diagram: — one is characterized by constructive separation of control (acknowledgement) board and of return-signal board and the other by a combination of the two.

Brown Boveri builds standard light diagrams to both designs. Of the big boards built so far, the majority are designed with separate boards. The equipment then consists of a supervisory board, of glass, which contains the light diagram of the system with the measurement devices lighted and of a separate control desk with exactly the same diagram but unlit and into which the control-acknowledgement switches are built. The indication of switching and voltage conditions is, here, quite independent of any action by the superintendent and the light diagram always reproduces faithfully the real existing operating conditions. It has been objected that this design with separate control desk, in which the control organs are mounted in a second diagram, may cause errors. This possibility is, however, removed by equipping the control switches with a testing position, between the "out" and "in" positions, and which must be passed over at every manipulation. If a control switch is on the testing position, the light diagram shows what the results of further rotation of the switch will be. If these indications are observed, the chance of error is no greater, here, than in the case of combination of control and return-signal devices on one board. There is even greater safety because there is an obligation to make a control reading with the help of the light diagram every time an operation is carried out; this control does not exist when the control and return-signal diagram are combined.

The other design makes use of a common signal and control diagram mounted on a sheet-metal board and composed of transparent rails. The hand-operated control-acknowledgement switches also serve as position markers and the automatic signalling of positions consists of a change signal which shows whether the switching handle really coincides with the existing switching position or has to be laid over by hand (thus if a breaker trips, the change signal lights up, until its control switch is turned to the "out" position).

Both designs can be said to be highly developed, to-day, and in use in many plants. A technical comparison gives broadly the following situation:—

The design with one common control and return-signal diagram allows of reducing the head space required because all the control-acknowledgement switches must be within reach of the operator. With the design with separate control desk, the light diagram can be placed where most convenient and the clearest arrangement of the lines and the advantageous distancing of the lines of the diagram can be adopted. Further, the control desk can be located far enough away from the supervisory board to allow of a clear general survey when carrying out control and acknowledgement operations. Even when heavy control switches are used, the control desk is considerably smaller than the light or supervisory board, because the latter also contains the metering devices the scale of which must be big enough to allow of easy reading without moving from one board to the other. The control desk becomes very small indeed when acknowledgement switches for the disconnecting switches, which are not as a rule remote-controlled, are done away with. This is quite allowable, as disconnecting switches cannot be moved automatically and are only supposed to be operated at the request of the load dispatching station. If, however, change signals are considered desirable for disconnecting switches, it is sufficient to have an acknowledgement push-button switch common for all the disconnecting switches which acts as recognition of the change in disconnecting switch position. The desk then contains only the considerably smaller number of control-acknowledgement switches for the circuit breakers on the system, which can be concentrated on a surface of about 1 m^2 even for big plants. As small a desk as this can be combined with the service engineers writing desk. The service engineer can then remain close to his telephone during the whole shift, a useful precaution, as the latter is indispensable to service despite all remote-signalling devices.

The design with a common light and control diagram is recommendable in most cases of supervision of small automatic substations and systems of general linear layout, such as are common in railway systems. They have the advantage, here, of allowing simple layout of the lines, due to the combination of control and return-signalling devices, and are somewhat cheaper.

Another aid to facilitate service is the indication of existing synchronism between the various power stations of the system. This information can also be obtained from the light diagram but, in big plants, it is troublesome to have to follow up the track of the current and errors may be made. Therefore, a direct indication of momentary parallel operation was desirable. This can be deduced, automatically, from the remote-signalled positions of the system breakers as was done for the voltage condition of the system. No signal lead is, therefore, necessary for this.

If the load-distributing station controls the breaker operations of the system, the device for automatic signalling of synchronism can be used to produce an interlock preventing faulty switching. This means very slight extra outlay so that this interlocking feature is warmly recommended. The connections used have been tried out in a large number of control stations for local control of big plants and have proved very useful indeed.

If the system to be protected is equipped with earth current extinguishing devices, it is the duty of the load dispatcher to check, in every case, if the compensation of the earth current is correct. To this end, a so-termed earth connection meter is used. This is an electric reproduction of the system with the help of which it is possible with the aid of a metering device to determine how strong the earth current would be under the momentary connection conditions of the system. A second measuring device is fed from a reproduction of the earthing devices (extinguishing coils or extinguishing transformers) and shows the momentary compensation current adjusted for. By closing and opening the circuit of individual extinguishing devices, or of tappings on the said devices, the compensation current must be then so adjusted that both measuring devices give the same readings.

Mention should also be made of what may be termed "desired load indicators" for the different power stations in the system. During parallel operation of several generating stations, it is important that the power they each deliver should be according to a programme fixed in advance. In order to check from the load dispatcher whether the said programme is held to, the installation of these indicators is recommended. With these devices, a given load programme is adjusted to, by hand. The indicating device for the corresponding real value of the load (real-load indicator) has a second pointer which indicates the desired value, so that too much or too little power delivered are recognized immediately.

(e) *The recording of service conditions on the system.*

The object of automatic records is twofold:— For ordinary service conditions, data is, thus, collected which allows of predicting what load and voltage conditions may be expected and of taking the necessary measures to meet the next occasion; in cases of trouble, recording helps to discover the cause of the trouble and to supervise the work done by the protective devices of the system. As generally, trouble phenomena is of very short duration, it can never be completely grasped without the aid of some auxiliary help like this. The automatic recording of the process of the disturbance is, therefore, of greater importance than the recording of the loads, because, if necessary, the latter data can be recorded by hand.

It is true that a relatively large number of recording devices are installed in existing plants and the partial load of each generating point is supervised by a lineal recording meter; but, even so, the recording is limited to the active power only and the centres of consumption are, also, left out. This last, especially, is not logical. Recording during ordinary service has as its chief object to provide data allowing an estimate to be made regarding future system loads. Where this power is generated is not of great importance. Further, the future power-delivery possibilities of the stations cannot be deduced from the data supplied by the recording devices. For the voltage distribution to be expected, records of power output are no assistance, if the repartition of the consumers on the system is not recorded. It is, thus, more rational to record the total consumption of the various points on the system, instead of recording the total output of the generating points, and to form the total therefrom. As telephone messages from the power-station engineers give information on the momentary power-delivery reserves, the load dispatcher has then all the data in hand for finding out the future power and voltage distribution and to allow of preparing the programmes for the various power stations.

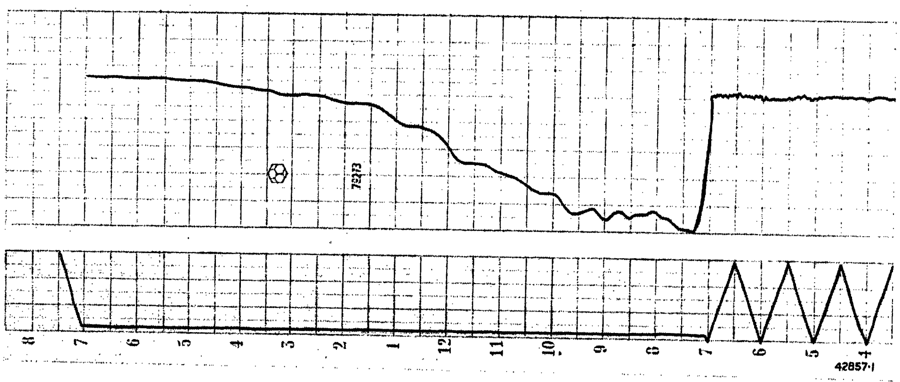


Fig. 9. — Recording paper strip of single-phase voltage trouble recorder.

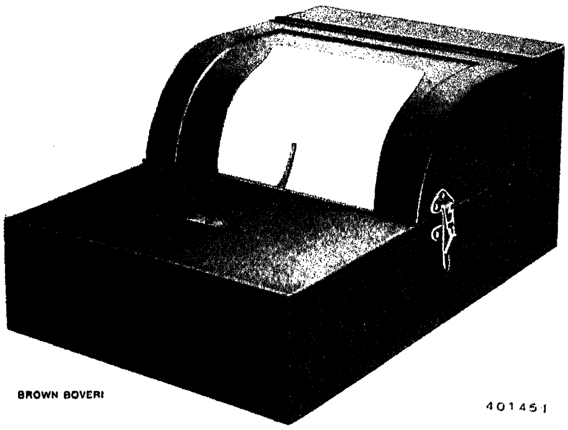


Fig. 10. — Switching recorder Type ZD 20, table type.

As regards recording to keep a control on cases of trouble, this must, above all, take into account that all disturbances in electric systems are very rapid phenomena. As recording devices, the so-termed trouble recorders, alone, can be used, with which a deviation of a measured magnitude from the value it should have produces, automatically, higher paper-strip speed. The length of paper strip which requires a period of 24 hours to run off under ordinary conditions, is then all paid out within the space of a few seconds. The recording strip shows, clearly, the process of the disturbance which occured. To make trouble supervision absolutely complete, trouble recorders for the system voltage, in all three phases, are required placed at the main generating points and for the total outputs of the different power stations. With the help of these records the phenomena arising at short circuits, earthings, power oscillations, etc. can be reconstructed fairly correctly. In the voltage recorders the change-over to higher paper-strip speed occurs when the voltage drops by some percent of the rated value. The change-over in the paper speed of the power recorders can be made dependent on the moment the change-over of the voltage recorders occurs. It is of great importance that both types of recorders should be accelerated simultaneously.

The automatic recording of the switching situation has been seldom carried out, up till now, because the requisite apparatus has only been on the market for a very short time. This equipment serves to lighten the work of the operators but, and above all, to give reliable data on the order in which automatic breaker trippings take place, for which purpose no hand-written record can suffice. The working speed of this apparatus corresponds to that of the trouble recorders but a change in paper-strip speed is not necessary because, under ordinary conditions the paper drum is at a standstill and only moves by the width of one line when a breaker is actuated.

Example of an automatically-registered record set up by a switching recorder.

Plant:— *Power station I.* Year:— *1936.* Months:— *May/June.*

Record of switching operations.

Day	Time	Switchings			Machines				Lines 100 kV				Lines 25 kV					
									North		South		Substation I		Substation II		Connection	
		Hand	Remote	Relay	1	2	3	4	1	2	1	2	1	2	1	2	1	2
30. V	0^h02					I			I	I		I	I	I	I	I	I	
	5^h14					I	I		I	I		I	I	I	I	I	I	
	6^h28	x			I	I	I		I	I		I	I	I	I	I	I	
	12^h08	x				I	I		I	I		I	I	I	I	I	I	
	13^h51	x			I	I	I		I	I		I	I	I	I	I	I	
	15^h49		x		I	I	I		I	I	I	I	I	I	I	I	I	
	20^h22		x			I	I		I	I		I	I	I	I	I	I	
	22^h37	x				I			I	I	I	I	I	I	I	I	I	
	23^h06		x			I			I	I	I	I	I	I	I	I	I	I
	23^h09		x			I			I	I	I	I	I	I	I	I		I
31. V	5^h12	x				I	I		I	I	I	I	I	I	I	I		I
	6^h27	x			I	I	I		I	I	I	I	I	I	I	I		I

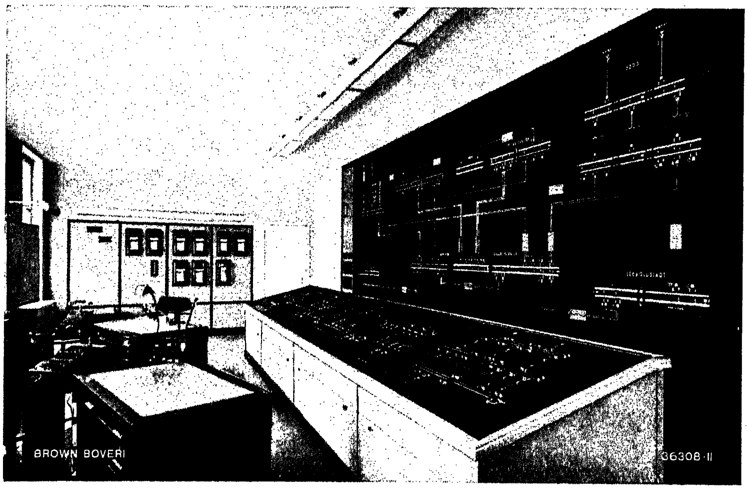


Fig. 11. — Load dispatcher for the 28-kV system of the Vienna Electricity Works, built in the year 1931 as first plant with complete equipment for remote control of a big-town supply system, by remote-metering of outputs, currents and voltages, as well as remote-signalling of breaker positions.

It is of importance that the type of device chosen should register the total switching situation of the station implicated after every breaker trip, this besides recording the changes in breaker positions. Only thus can the conditions existing at any given moment be determined without considerable trouble.

(MS 510) *O. Plechl. (Mo.)*

NOTES.

Electric-boiler plant of Brown Boveri design in the Fédération Laitière du Léman, Vevey.

Decimal index 621. 181. 646.

THE operating characteristics of this electric-boiler plant are the following.

Maximum continuous load:—	800 kW, corresponding to a production of steam of about 1200 kg/h
Voltage:—	3800—4000 V
Current:—	Three-phase, 50 cycles
Maximum allowable operating pressure:—	8 kg/cm² abs.

There is no condensate available for supplying the electric boiler and fresh water is used for the purpose which is fairly hard (12·2° German degrees) and which, therefore, must be treated chemically before being utilized.

The water-softening plant consists of a Lamy softener with Neolite filter, working on the base-exchange process and a maximum volume passed of 1·5 m³/h. The total volume passed between two regenerations amounts to 8 m³ corresponding to one regeneration per day.

The softener is very small and works without any attendance; it is equipped with a water meter, having an alarm device, the duty of which is to inform the attendants of the end of an operating period between two regenerations.

We have, here, a typical example of an electric boiler plant which does not make use of condensate and in which the relatively hard water available is treated in a chemical water-softening plant, working on the base-exchange principle.

The feeding of the electric boiler with chemically treated water containing a great deal of salt and of low specific electric resistance is possible thanks to the excellent properties of the Brown Boveri water-jet electric boiler. This design allows of using boiler water of a far higher salt content than in any other existing type of boiler, because the voltage drop takes place along the line of the water spray. The blow-down quantity of water necessary to keep the concentration within the admissible limit and the heat losses which are entailed thereby are small. If it is considered desirable to recuperate the heat carried off by the blow-down water, this can be effected, practically entirely, in a small and cheap heat exchanger.

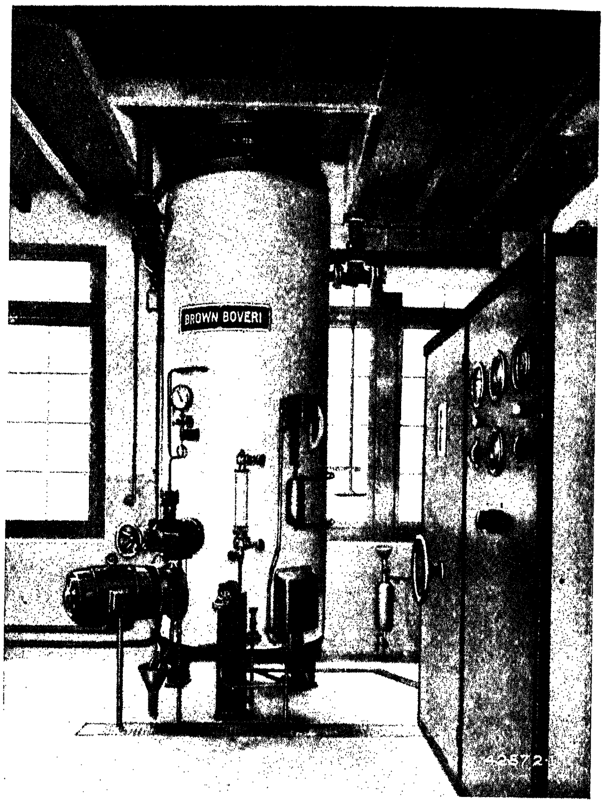


Fig. 2. — Fédération Laitière du Léman, Vevey. Electric-boiler plant 800 kW, 4000 V, 8 kg/cm² abs.

The chemical water softener according to the base-exchange process (Neolite, Zeolite, Permutit, etc.) has great advantages as compared to other systems as it takes up very little room and is easy to attend. Its running charges are slightly higher on account of the cost of the regenerative salt used, but can be balanced again by using a Brown Boveri boiler with its small quantities of blow-down water.

The diagrammatic layout of the whole plant is shown in Fig. 1. The softened water flows from the Lamy softener 7 in to the feed-water tank 6. The flow to this tank is regulated by a float valve, thus, only that amount of water is allowed to flow through the softener which is utilized in the boiler and, if no water flows through the softener, no Neolite salts are used. The feed pump 5 draws water from the feed-water tank and drives it through the heat exchanger 3 into the boiler 1. The heat exchanger works on the counter-

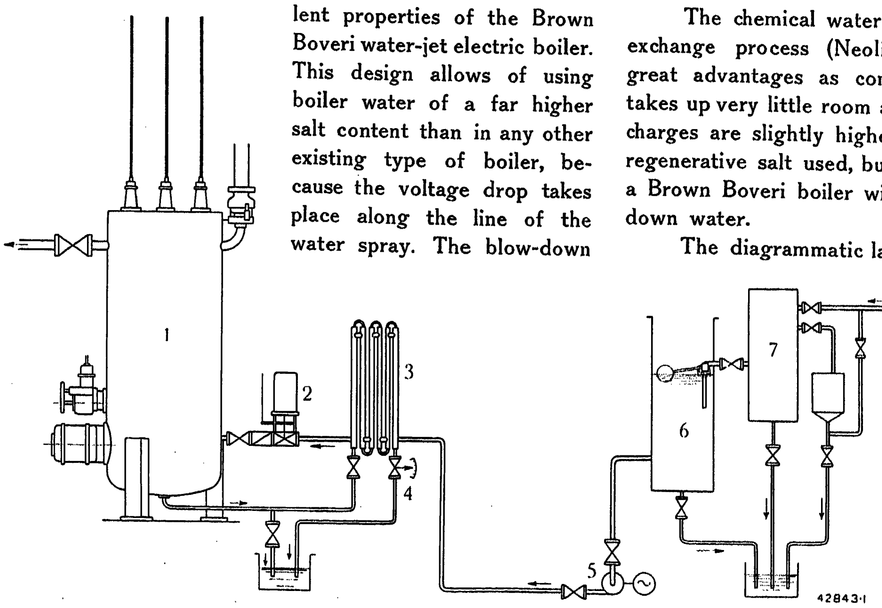


Fig. 1. — Fédération Laitière du Léman, Vevey. Electric-boiler plant 800 kW, 4000 V, 8 kg/cm² abs. General diagram of layout of the electric boiler with Neolite water softener.

1. Electric boiler.
2. Regulating for valve feed water.
3. Heat exchanger.
4. Blow-down valve.
5. Feed-water pump.
6. Feed-water tank.
7. Neolite water softener.

flow principle and is so dimensioned that the blow-down water which flows out of the boiler at about 170° C is cooled down to about 5° C above the temperature of the feed water, under full-load conditions. Thus, the heat contained in the blow-down water is, practically, all recuperated.

The amount of feed water fed to the boiler is regulated automatically and according to the boiler load.

The quantity of blow-down is regulated by a special valve equipped with a calibrated scale. Thus, the plant attendants can adjust the amount of blow down to the boiler load. We also deliver, if required, blow-down regulating devices which work entirely automatically and which keep the concentration of the boiler water at the maximum admissible value independently of the load or the amount of salt in the feed water.

Further, the electric boiler has a pressure regulating device which ensures that the pressure will be maintained practically constant, when load fluctuations occur between no load and full load.

Fig. 2 shows the complete plant. The high- and low-voltage switchgear is mounted beside the electric boiler. The switchboard layout is such that the control instruments on the board can be kept under easy observation when the boiler apparatus is being manipulated. Thus, the operating conditions of the plant and the way all the organs function can be supervised from the same spot.

Started up in March, 1936, this electric boiler plant has been working since then, continuously, to the entire satisfaction of the owners.

(MS 508) *E. Soldati. (Mo.)*

The different ways of driving Brown Boveri Frigiblocs.

Decimal index 621. 576. 3.

A fundamental characteristic of the Brown Boveri Frigibloc, which forms, in itself, a complete refrigerating plant, is its gas-tight quality. This complete refrigerating plant, composed of compressor, motor, condenser, evaporator and all auxiliary and regulating gear is enclosed in a gas-tight housing. Apart from compactness, the chief aim pursued in the design was the elimination of all sealing glands to the outer air on the shaft of the compressor set. Fig. 1 shows the standard Brown Boveri Frigibloc. It is, at once, apparent that the different elements have been combined to form a whole, in a practical and pleasing manner. The Frigibloc is built up of organs all of which were well-known already and had been thoroughly tried out; further, it is protected from possible trouble by automatic safety devices. The Frigibloc refrigerating machine is very suitable for commercial and industrial plants, on account of the little space it takes up and the minimum of attendance it demands, and this also in plants where specially skilled operators are not available.

In many concerns where refrigeration is required and notably in chemical works, where steam is needed for industrial processes, it is often found desirable to drive the Frigibloc by steam turbine. In cases like this, the object is to take as great advantage as possible of the advantages inherent to steam-turbine drive, which permits speed variation over a wide range, with practically no losses and, thus, allows of suiting the refrigerating output to variable service requirements. The primary conditions required for steam-turbine drive are fulfilled by the Frigibloc a priori because the compressor used is of the turbo type. The utilization of a steam turbine obviously leads to a design of the Frigibloc with sealing gland as it is impossible to lodge the steam turbine itself inside the gas-tight housing. This gland is of the labyrinth type supplied with sealing oil. The latter flows to the parts to be sealed from an oil reservoir and under a slight head; after passing over the said parts it is collected and driven back by a small pump to the oil reservoir, above. Obviously, great care was devoted to giving as little play as possible, in the gland proper. This object is attained by a special gland design and cradling. At one side, the gland is bolted to the compressor housing and, on the other side, it is secured to the wall of the Frigibloc housing through the intermediary of a flexible organ. In this way, the gland is screened from all influences due to heat stressing, so that the play adjusted to is maintained. This Brown Boveri gland has given a very excellent account of itself after years of service in various plants.

Thanks to the qualities of the Brown Boveri sealing gland, the Frigibloc of the design in question is entirely gas-tight, like the standard type without gland. It should be mentioned here that the cooling mediums used in Frigiblocs work with service pressures on the evaporator side which are always below atmospheric pressure and, on the condenser side, generally below or very little above atmospheric pressure. Thus, in case of an accidental leakage, no gas can escape and, at the most, only a little air can penetrate into the Bloc; an occurrence which is instantly signalled by a supervising apparatus, so that the air which

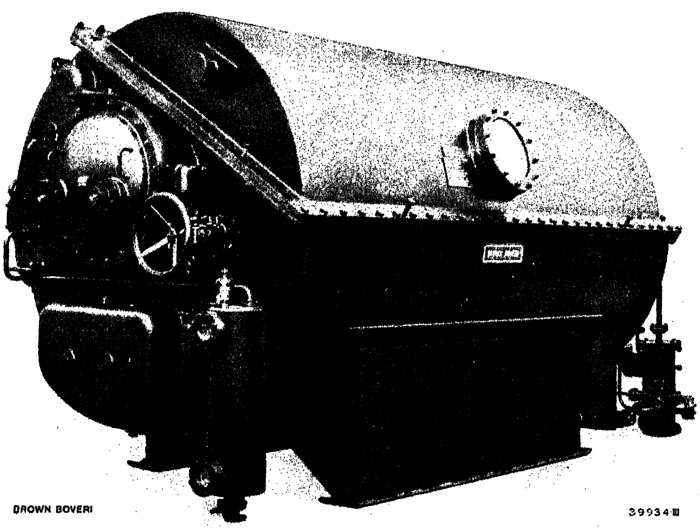


Fig. 1. — Standard Brown Boveri Frigibloc without sealing gland, for a refrigerating capacity of from about 25,000 to 2·5 million kcal/h. Drive of the refrigerating compressor by an A. C. motor. The entire refrigerating plant is enclosed in a gas-tight housing.

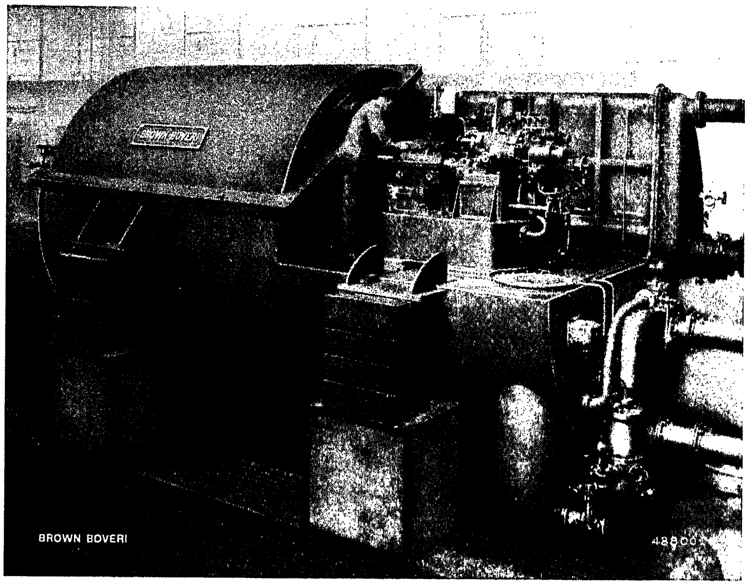


Fig. 2. — Brown Boveri Frigibloc, 1·5 million kcal/h, on the test bed. Design for drive by a steam turbine and intended for an artificial-silk mill.

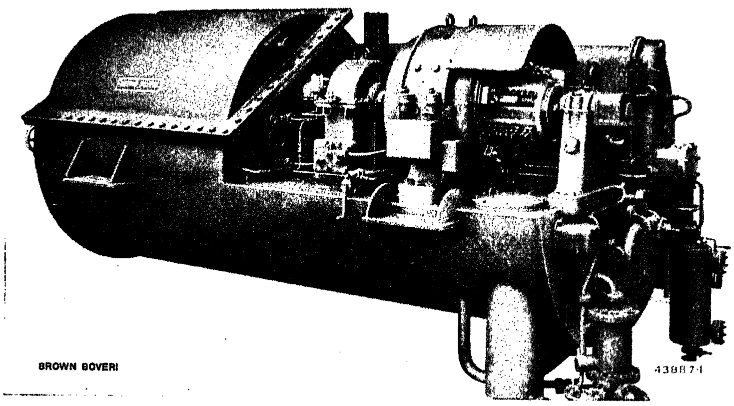


Fig. 3. — Brown Boveri Frigibloc, 320,000 kcal/h. Design for drive by a D. C. motor and intended for use on board ship.

has penetrated into the Bloc can be pumped out again by a device supplied with all standard Frigiblocs.

Fig. 2 shows a Frigibloc built for steam-turbine drive to the design described. This is a Frigibloc for an artificial-silk mill and it has a capacity up to about 1·5 million kcal/h. As is generally known, a considerable refrigerating capacity is called for in artificial-silk manufacture. The illustration shows the Frigibloc on the test bed in the Baden workshops.

The advantage inherent to steam-turbine drive from the point of view of regulation over a wide range, can also be obtained when the drive is by a D. C. motor. There are, theoretically, no fundamental drawbacks to lodging the D. C. motor in the gas-tight housing because Brown Boveri electric motors subjected to the influence of a refrigerating medium are of special design, according to the experience gained in long practice. Nevertheless, it is generally considered preferable to lodge D. C. motors outside the Frigibloc proper. One reason for so doing is the supervision of the commutator and of the commutation of D. C. machines which, though requiring little attention, cannot be absolutely dispensed with. Fig. 3 shows a Frigibloc with drive by D. C. motor. This unit has a refrigerating capacity of 320,000 kcal/h and is of a design of which Brown Boveri delivered two to a beer brewery. The pleasing compactness of the design of the refrigerating plant is very evident in this unit. Designs according to Fig. 3 are also suitable for air conditioning on board ship.

Finally, it should be said that the compressors of Frigiblocs can be driven by internal combustion engines such as a petrol or Diesel engine, and there is no difficulty about this. In such cases, direct drive is generally replaced by electric power transmission or by a reduction gear or belt combination. The electric transmission has the great advantage that the generator coupled to the combustion engine can be designed to supply A. C. for the compressor proper and for the other auxiliary motors; thus standard Frigibloc without a sealing gland to the outer air can be used. At the same time, Brown Boveri have made a study of the aforesaid reduction-gear and belt drives so that practical solutions of these problems are available.

The preceding remarks show that the Frigibloc can be coupled with any type of driving engine encountered in practice, this without sacrificing any of its valuable fundamental characteristics.

(MS 517) *R. Gilly. (Mo.)*

Brown Boveri drive of a double rotary printing machine.

Decimal index 621.34 : 681.624.4.

At the beginning of 1936, a rotary printing machine, the drive of which was delivered by Brown Boveri, was started up in the Il Telegrafo printing works in Livorno (Italy). This is a four-reel double rotary printing machine equipped with two folding machines and built for a maximum of 15,000 cylinder rotations per hour (Fig. 1). It is driven by two three-phase shunt commutator motors each of 45 kW; there is also one auxiliary drive for each half, respectively, for introducing the paper and performing other auxiliary duties. Each of two main drives is controlled by push-button switches, grouped in several control posts and conveniently located on the attendance side of the machine. The two main push-button posts by which, among other operations, the printing speed of the machine can be regulated, are placed just beside the two folding machines, as the supervision of the printed and finished newspapers is carried out at this point.

Only three-phase shunt commutator motors were taken into consideration for the drive of the rotary machine, because they also maintain their ordinary stability at smaller loads, as well. The smaller load on the motors

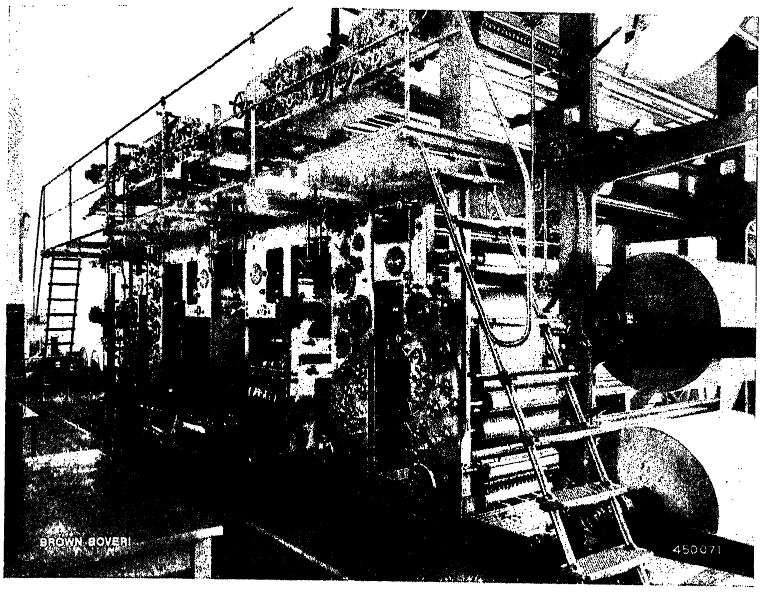


Fig. 1. — Il Telegrafo, Livorno (Italy). General view of the double rotary printing machine.

occurs when a paper with a small number of pages is being printed and a printing unit of each machine half is cut out. Further, the shunt commutator motors have the advantage of allowing speed regulation without loss and this smoothly over a range of 1 to 5, simply by displacing the brushes. Starting up is accomplished smoothly with these motors.

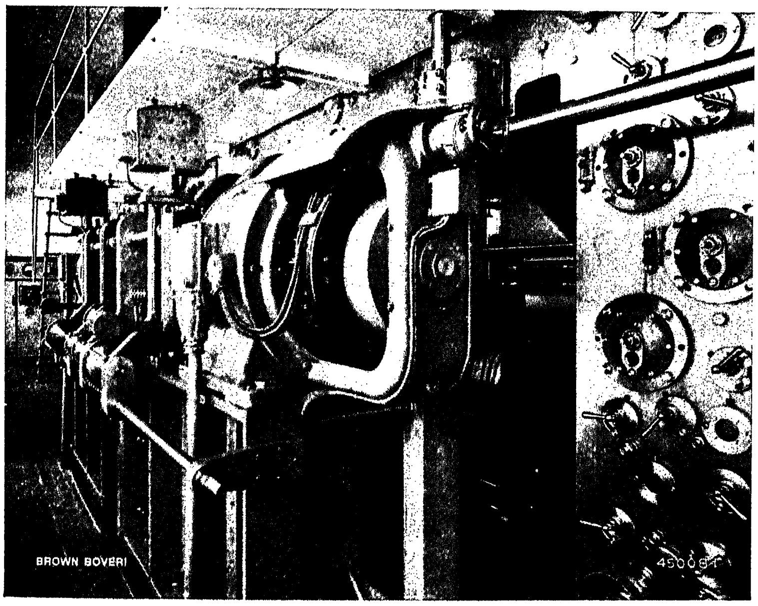


Fig. 2. — Driving set of one machine half, 45 kW output.

When the machine halves are coupled together, the control of both drives can be so connected through the intermediary of a switching drum, that both drives are controlled, simultaneously, by the push-button of any one control post. A switch combined with the machine coupling only allows of the machine being started up when the positions of this coupling and the aforementioned switching drum coincide. Apart from this, the drives are provided with all the safety devices necessary to prevent the machines being started unintentionally, when they are being rotated by hand or when work is being carried out inside them.

There is a special relay to ensure equal load distribution when the shunt commutator motors work in parallel; this relay is cut out, automatically, when the two drives are switched to individual drive of each half of the machine.

Fig. 2 shows the double rotary machine from the driving side; one of the two shunt commutator motors with built-on motor drive of the brush gear is shown very clearly. The switching cubicle which contains all the switchgears for the double drive, is seen in the background. Apart from the measurement instruments and the main circuit breaker, the aforementioned relay for equal load distribution is seen in the centre of the cubicle; below is the lever control for the paralleling switch drum.

The whole plant has operated perfectly from the time it was started up.

(MS 519) *A. Auer. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2) : 621. 313. 322.

In the year 1897, Brown Boveri delivered a three-phase alternator to the Biel-Leubringen (Canton Berne) funicular railway. This generator was of the well-known W 3 type delivering about 40 kW at 2200 V, 40 cycles, 820 r. p. m. The exciter was of the built-on type. After having been in service, for many years, on the said funicular railway, the generator was taken over by the Leubringen Municipality and has been utilized, since then, to provide the lighting of their pumping station.

This generator is designed with the high-voltage winding in the rotating armature while the magnetic field is fixed and has six poles. Externally, it ressembles the alternator delivered to Messrs. Oederlin & Co., Ennet-Baden (Switzerland), an illustration of which appeared in The Brown Boveri Review, March 1936, page 100. As in the case of the latter machine, the unit described here has never called for any major repairs and it is running perfectly, to-day, both mechanically and electrically.

(MS 993) *Prop.*

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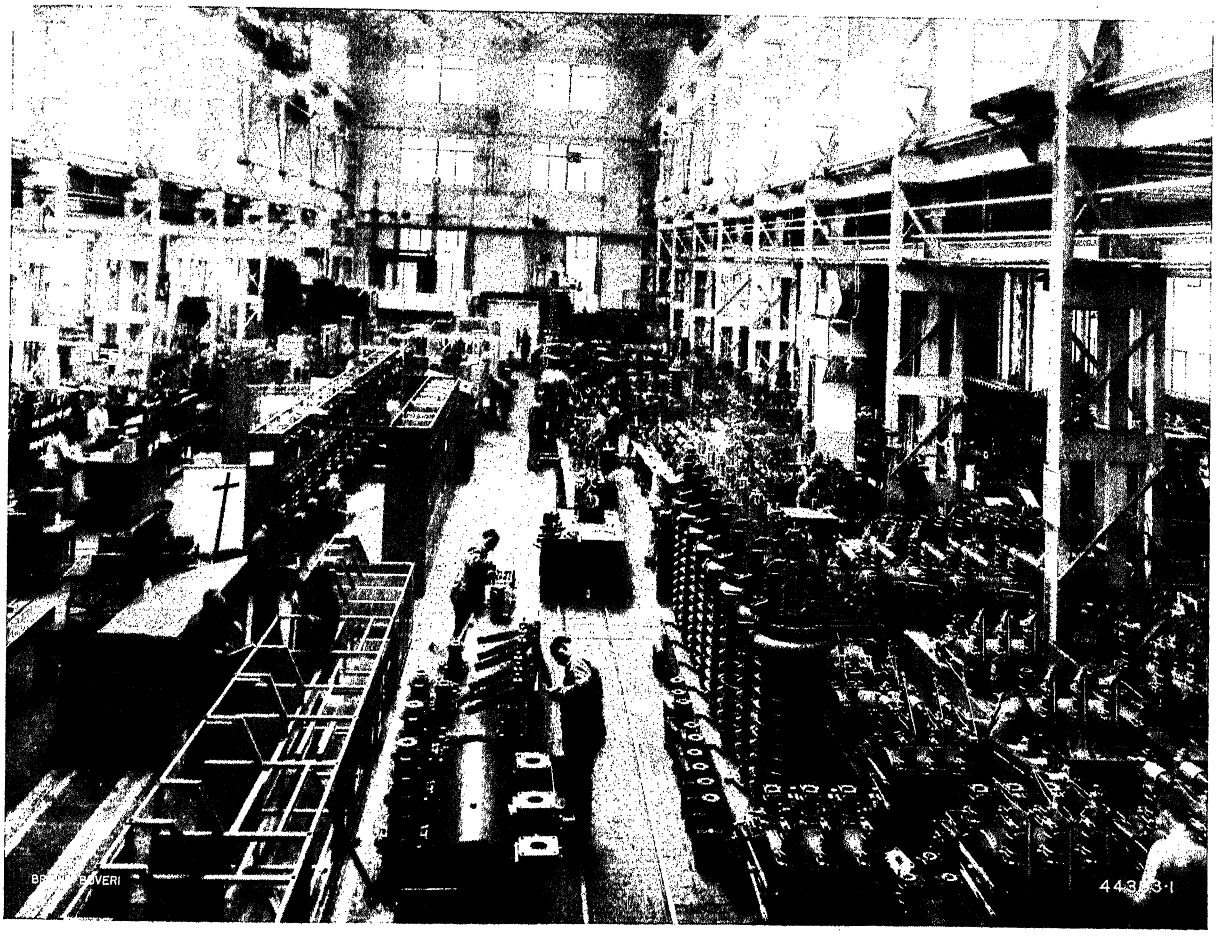
GENERAL INDEX TO VOL. XXIII, JANUARY-DECEMBER, 1936.

FRONTISPIECES AND SEPARATE ILLUSTRATIONS.

VOL. XXIV JANUARY/FEBRUARY, 1937 (DOUBLE NUMBER) No. 1/2

THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



INTERIOR OF SWITCHGEAR SHOP OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND).
(Taken at end of 1936.)

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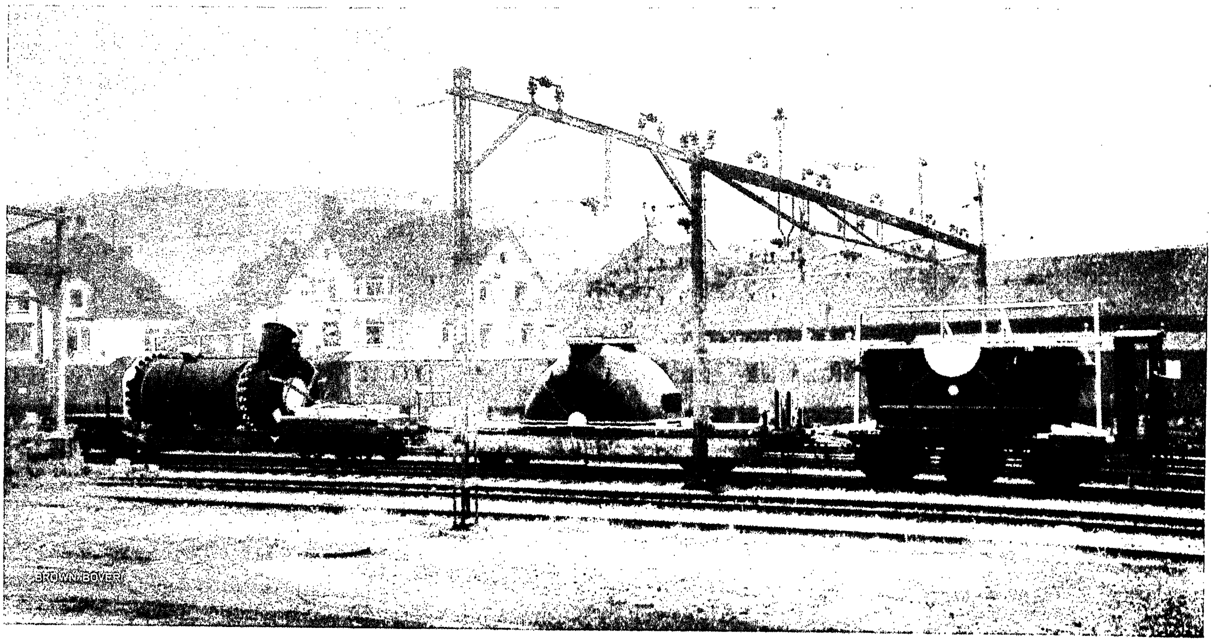
Printed in Switzerland



The main equipment of the Velox Power Station of Oslo: a Velox steam generator and a 32,000-kW turbine ready for despatch in the Baden railway station.

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THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIV JANUARY/FEBRUARY, 1937 No. 1/2

PROGRESS IN BROWN BOVERI DESIGN DURING 1936.

INTRODUCTION.

Decimal index 621.3.

A retrospect of the work of development accomplished from one year to the next brings a realization of the amount of effort and expense which go to the evolving of a complete machine, from its first technical conception. A whole series of preliminary tests must be carried out before even a basis for the calculation of the main dimensions is laid and it is only after numerous draft plans have been drawn up that a really definite design and the workshop drawings belonging thereto can be made. Then comes the practical building of the new machine which sets the builder problems to solve as, not infrequently, new methods and new machine tools are required. The machine, once completed, is ready for the test bed and every experienced engineer is aware that, whatever care may have been devoted to calculations, design and construction, weaknesses are likely to crop up at this stage, all of which must be remedied. Clients who are far seeing enough to grasp the possibilities of a quite new product and are, also, confident enough to give it a trial, must now be looked for. We owe much to a number of far-sighted men who have been ready to take the responsibility inherent to putting a quite new type of machine into their own plant. We have been fortunate to find such friends in the fields of the steam turbine, turbo-compressor, high-pressure steam generating plant as well as in that of Diesel-charging and of the Velox steam generator; the same applies to the mutator, the circuit breaker and distribution system protection. Such clients are, of course, not easy to find and the field of technical development in many branches owes a debt of gratitude to their far-seeing and pioneering spirit.

We would recall that the development of the steam engine took several generations to complete, as every step forward had to be based on new experience and painstaking tests. To-day, the scientifically equipped engineer has thoroughly-developed methods of calculation and of testing to help him and he is backed up by well-equipped laboratories, so that any idea considered worthy of practical evolution can be perfected in a far shorter time than in earlier days. It is this accelerated pulse of technical progress which justifies us in presenting a yearly summary of the development work we have accomplished in the preceding twelve months.

I. POWER PRODUCTION

A. STEAM POWER PLANTS.

1. *Velox power stations.*

A big *Velox power station*, entirely designed by our power-plant department with the collaboration of Norsk Elektrisk Brown Boveri, Oslo, was put into service towards the end of last year. This station is an enlargement of the older 12,000-kW "Rosenkrantzgate" power house and it is located in the centre of the town of Oslo. The new station contains two Velox steam generators each producing 75 t/h of steam, a 32,000-kW steam turbine with its condenser and generator and all auxiliaries, transformers and switchgear plant. It is, really, a peak-load and stand-by power station to complete and assure the power supply to the town of Oslo, which, under ordinary conditions, is supplied from hydraulic power stations. A Velox plant was chosen, here, because of the rapidity with which it can be started up, because it produces no smoke and, also, because it takes up very little space, all qualities in which the Velox is superior to any other type of steam generating plant. There was

less space available for the whole new plant (including sufficient room for a third similar Velox and a 20,000-kW electric boiler) than that which was taken up by the old boiler house, alone. To-day 42 kW per square metre floor surface are produced as against 10 kW in the old power house, which was, itself, far from being amply dimensioned.

The Oslo Velox Power Station was built in a remarkably short space of time. Work on dismantling the old boiler house began at the beginning of 1936. The new foundations were in place by May and June, part of which foundations are carried on a framework of piles and part on rock. At the same time, the crane-rail tracks and their supporting columns were strengthened and bigger cranes put in. Erection work on the Velox units and the turbine was begun in July and the plant was set to work as early as the middle of November.

Fig. 1 shows an interesting view of both the 75-t Velox steam generators and of the 32,000-kW turbine of the Oslo plant, while it was still on our test bed. This is certainly the first occasion in the whole history of technical development in which a complete power plant of such considerable output, consisting of steam generator, turbine with apparatus, piping, etc. has been mounted complete and tested

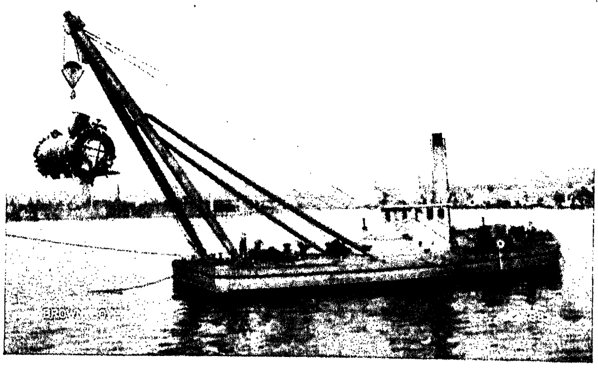


Fig. 2. — A Velox steam generator for 75 t/h of steam for the Oslo power station being landed by means of a floating crane.

on the manufacturer's test bed. Every engineer familiar with power station building will appreciate the value of this possibility offered by the Velox of having the whole plant tested complete before it is despatched. The transport conditions of the Velox plant in question, which was sent away after dismantling into a few main parts, only, offered some interesting points. Fig. 2 shows the combustion chamber which is the biggest part of the Velox being landed in Oslo harbour with the help of a floating crane. Finally Figs. 3 and 4 show two interior views of the new Rosenkrantzgate Power Station. The Velox units and

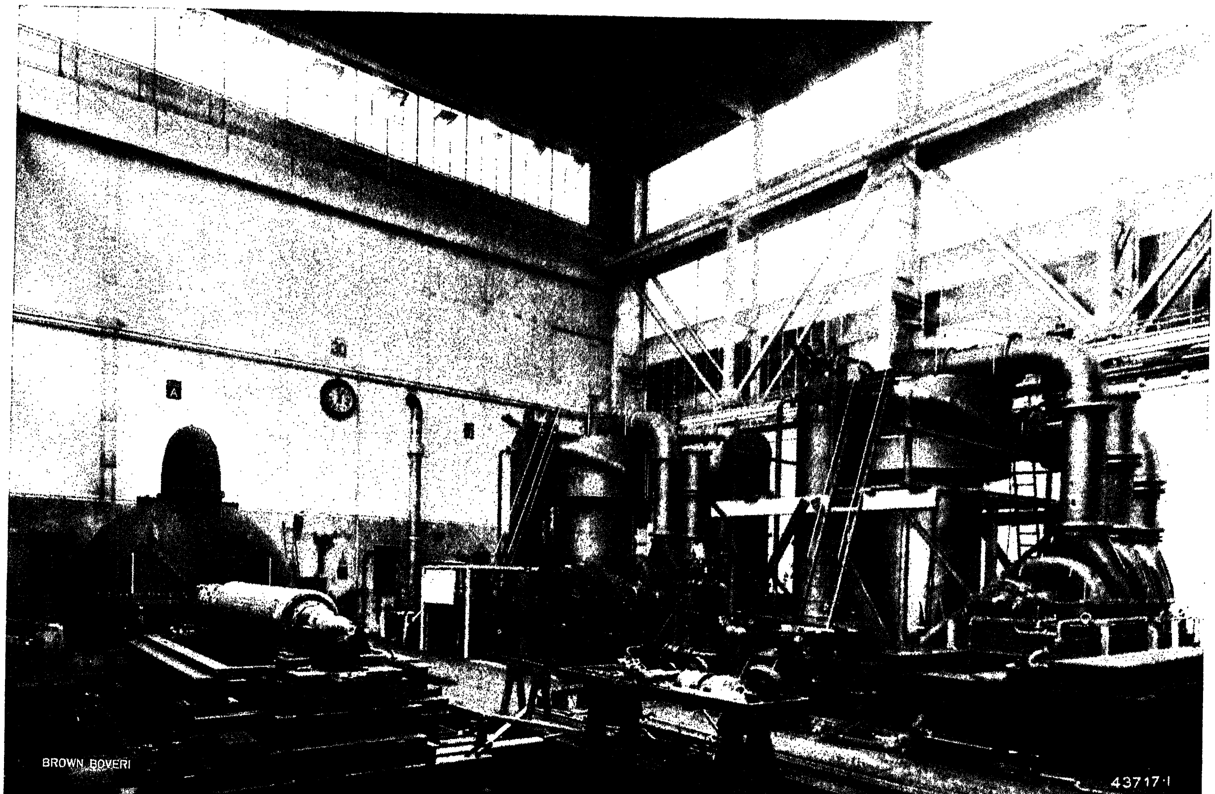


Fig. 1. — The power-generating plant of the Velox power station of Oslo, on the Baden test bed. It is composed of two Velox steam generators each for 75 t/h of steam and of a 32,000-kW steam turbine with generator.

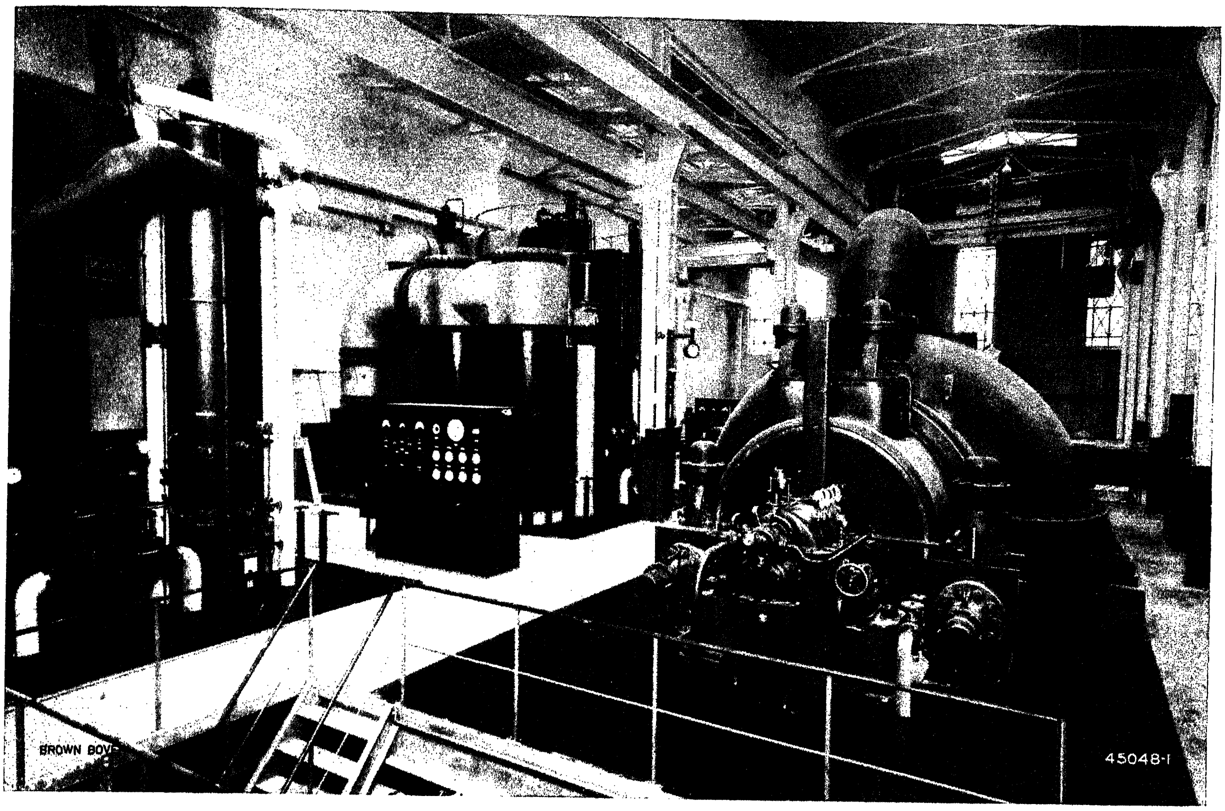


Fig. 3. — Velox steam power station of Oslo. Two Velox steam generators each for 75 t/h of steam and a 32,000-kW single-cylinder steam turbine.

the turbine are seen and it will be noted that they are not crowded together in an undesirable way, despite the restricted space available.

No power plant, whatever the source of its power may be, takes up as little room, for a given output, as does the Velox with its steam turbine. The Velox has a considerable future in the design of *bomb-proof power stations* which are, unfortunately, a problem with us, to-day. Such plants are covered in by massive concrete arches or else hollowed out of the rock. Space saving is, thus, of primary importance in order to keep cost low and reduce target surface for bombs and shells. Fig. 5 is a typical example of the design of a bomb-proof Velox power station for 20,000-kW output. It is designed to be lodged in a tunnel excavated in the rock and having a section similar to that of a two-track railway tunnel. This plant comprises a Velox steam generator to produce 80 t/h of steam, a steam turbine with its condenser, a 20,000-kW generator, all accessories and the switchgear plant. There are oil tanks in this bomb-proof chamber and the capacity of the said tanks allows of generating two million kWh which is sufficient for 6—7 days service.

Fig. 6 is a suggestion for an underground bomb-proof Velox steam generating plant for producing 12,000 kg/h of steam. This would be a stand-by boiler plant for an industrial works, which would be dangerously situated in case of hostilities.

The following chapter gives test results from which it will be seen that a 45-t Velox steam generator was got under full head of steam in $3^1/_2$ minutes, starting from the stationary cold state. This extremely short starting-up time opens up interesting possibilities for the layout of *stand-by steam power stations* combined with Velox steam generators. The following two cases may be examined here:—

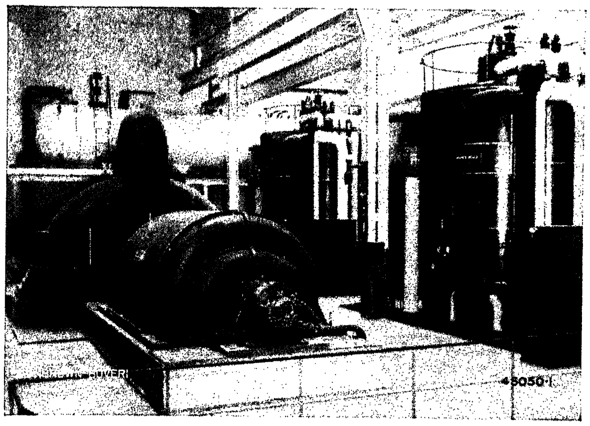


Fig. 4. — Velox power station of Oslo, seen from the generator side.

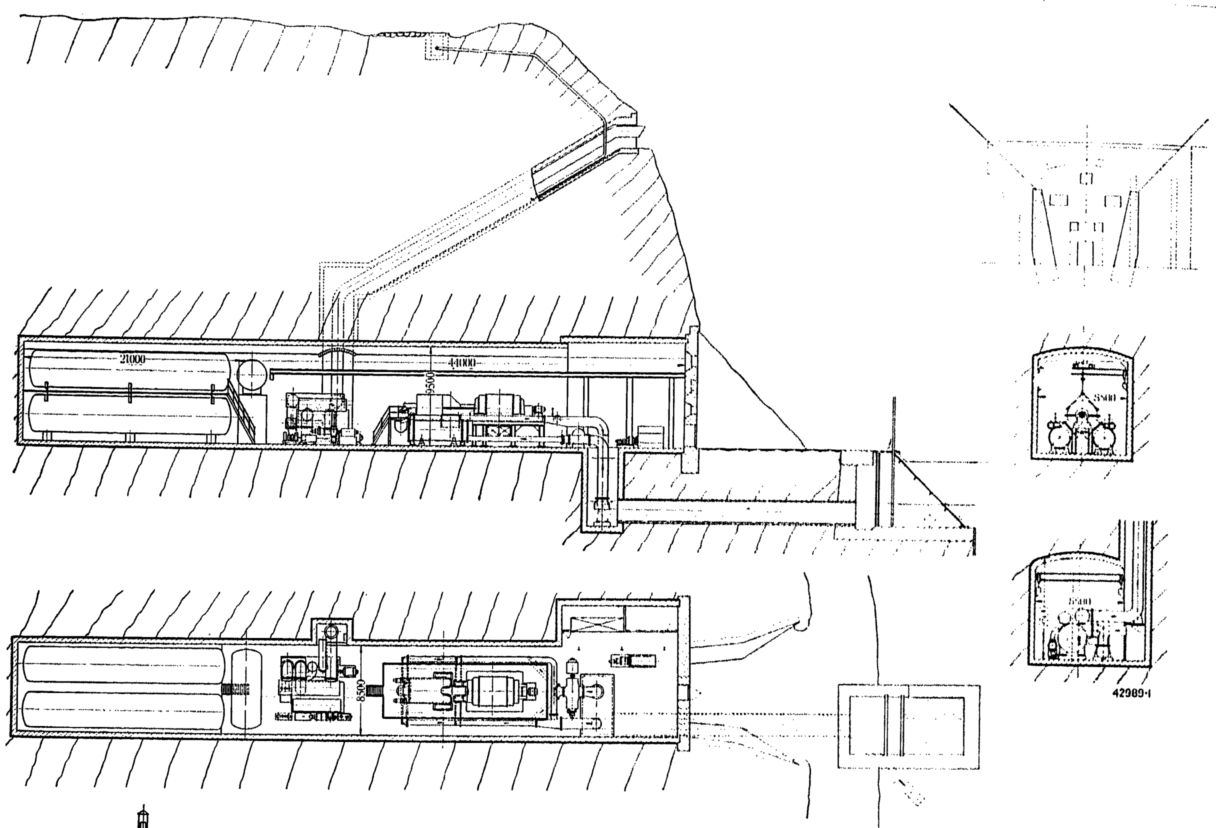
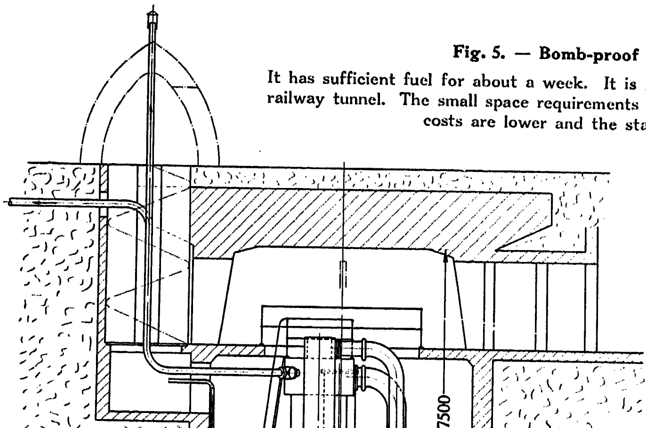
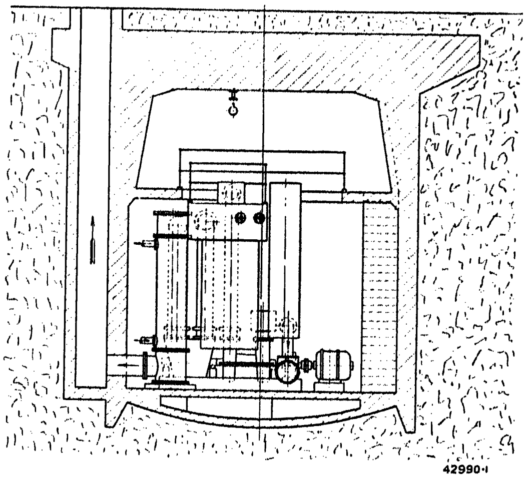


Fig. 5. — Bomb-proof Velox power station to produce 20,000 kW.

It has sufficient fuel for about a week. It is located in a tunnel in the rock having the section of a double-track railway tunnel. The small space requirements of the Velox make it very suitable to bomb-proof stations, as building costs are lower and the station offers a smaller target to enemy projectiles.





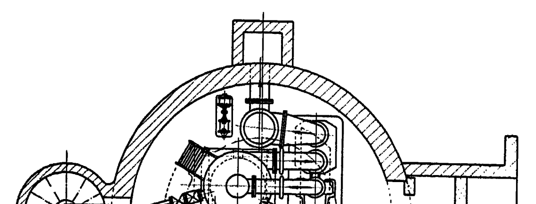


Fig. 6. — Bomb-proof Velox steam generating plant.

Planned to produce 12,000 kg/h of steam and intended for an industrial plant which would be rather vulnerable in case of hostilities.

1. The stand-by power station to act as a *quick-acting stand-by plant* and be started up after the disturbance of ordinary service has occurred; it must be able to take over load within a few minutes.

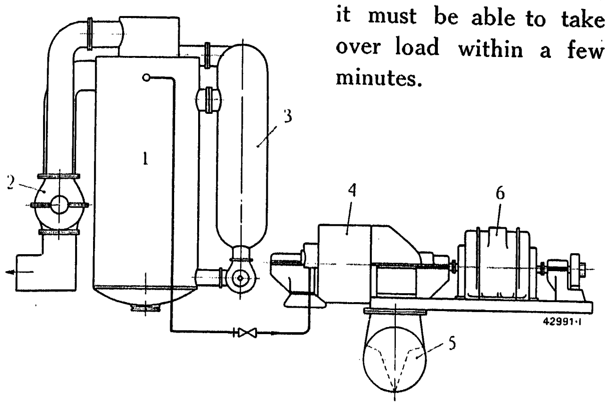


Fig. 7. — Diagram of a quick-acting stand-by power plant with Velox steam generator, which can be started very quickly and even automatically, if so desired, when trouble occurs on the distribution system. It can take over full load in 5—8 minutes.

1. Combustion chamber of Velox.
2. Charging set.
3. Steam separator.
4. Steam turbine.
5. Condenser.
6. Generator.

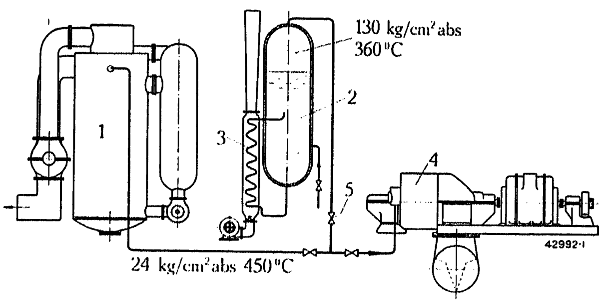


Fig. 8. — Diagram of an instantaneous-action stand-by power plant with Velox steam generator and high-pressure bridging accumulator which takes over load, immediately, when trouble occurs on the distribution system and prevents any interruption in current distribution.

The turbo-set runs continuously as phase advancer. In case of trouble it is fed from the steam accumulator, until the automatically-started Velox takes over load.

1. Velox steam generator.
2. Bridging accumulator.
3. Oil-heating to charge accumulator.
4. Turbo-generator.
5. Throttle valve.

2. The stand-by power station to act as an *instantaneous-action stand-by plant* and prevent any interruption of power delivery at all.

Generally, the first type of stand-by plant should suffice for industrial services, railway power stations, small communities, etc., while the second type is desirable for big towns.

A diagrammatic illustration of the quick-acting reserve plant is shown in Fig. 7. This is a standard Velox and turbo-set plant which is started up very rapidly and, if so desired, automatically. It can take over full load in about 6 to 8 minutes.

Fig. 8 shows the instantaneous-action reserve plant, composed of a Velox, a turbo-set and a so-termed *bridging high-pressure steam accumulator.* Velox and turbine are built for 25 kg/cm². The accumulator is charged up to 130 kg/cm² by means of a small oil-firing equipment or similar gear and delivers steam through a throttle valve to the 25-kg/cm² steam system. During the waiting period the turbine runs at full speed with open admission valve but closed governing valves it being driven by the generator running as a phase advancer. The condenser is working (with reduced cooling water volume) so that the turbine can run on vacuum, with lower losses. As soon as the failure of other sources of power cause the generator to take over power delivery, the governing valves of the turbine open, according to the action of the turbine governing system, and the turbine delivers power. The accumulator supplies steam until the Velox steam generator takes over from it. The Velox is started automatically by making the valves of the gas turbine of the Velox open at the same time as the governing valves of the main turbine, and by making the charging and pump set run on steam from the accumulator. In this way the Velox can be brought to full delivery in about 3 to 4 minutes, especially when the accumulator keeps it under pressure; thus the high-pressure steam accumulator can be of small dimensions and inexpensive.

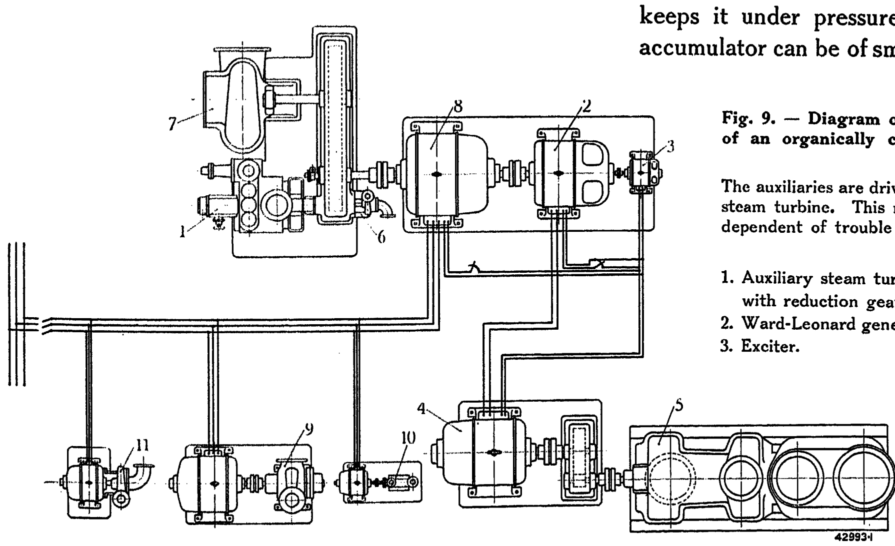


Fig. 9. — Diagram of auxiliaries of a Velox motor, i. e. of an organically combined Velox steam generator and turbine.

The auxiliaries are driven, directly or indirectly, by an auxiliary steam turbine. This renders the drive of the auxiliaries independent of trouble on the system, in the power house or on other sets.

1. Auxiliary steam turbine with reduction gear.
2. Ward-Leonard generator.
3. Exciter.
4. Ward-Leonard motor.
5. Charging set.
6. Feed pump.
7. Cooling-water pump of condenser of main turbine.
8. Three-phase generator which is, also, a starting motor.
9. Circulation pump.
10. Fuel pump.
11. Condensate pump.

When on this subject, the *problem of auxiliaries for the boiler and turbine plant* can be treated briefly here, as well. The reliability of these auxiliaries and their drives are of primary importance to the reliable operation of the whole power station. Above all, measures must be taken that trouble on the electric system does not cause the driving motors of the said auxiliaries to fail and thus shut down the whole plant. According to old Brown Boveri practice, the motor-driven pumps of the condensing plant are provided with a spare turbine, this in the case of plants having big main steam turbine sets; the spare turbine starts up automatically, if current fails, and takes over the auxiliary drive. The drive of the auxiliaries of the Velox plant must be assured similarly, if it is desired to keep up the service of the power station when current fails. In order to avoid having such a large number of small auxiliary turbines, we have, recently, created an arrangement such as the one shown in Fig. 9 which is intended for a plant containing a Velox and main steam turbine with condenser. The auxiliaries are driven from *one* auxiliary turbine instead of from the electric supply system. The exhaust of this turbine is carried to an intermediate stage of the main turbine, in small stations, in order to increase the economic qualities of the plant; in big plants the exhaust of the auxiliary turbine goes to the condenser. The auxiliary turbine drives the following units directly:— the Ward-Leonard generator and its exciter for the drive and regulation of the Velox charging set, the Velox feed pump, the circulating water pump of the condenser as well as a small three-phase generator. The latter drives electrically and separately the circulation pump of the Velox, the fuel pump and the condensate pump of the condensing plant, because these apparatuses have to be located in definite parts of the plant. The auxiliary generator works as a motor at starting, getting current from the electric system or, if the latter is dead, from an auxiliary Diesel set or a petrol-engine generator set. All auxiliaries of the power station are, thus, entirely independent and trouble on the electric system, or caused by other machines, does not disturb their working.

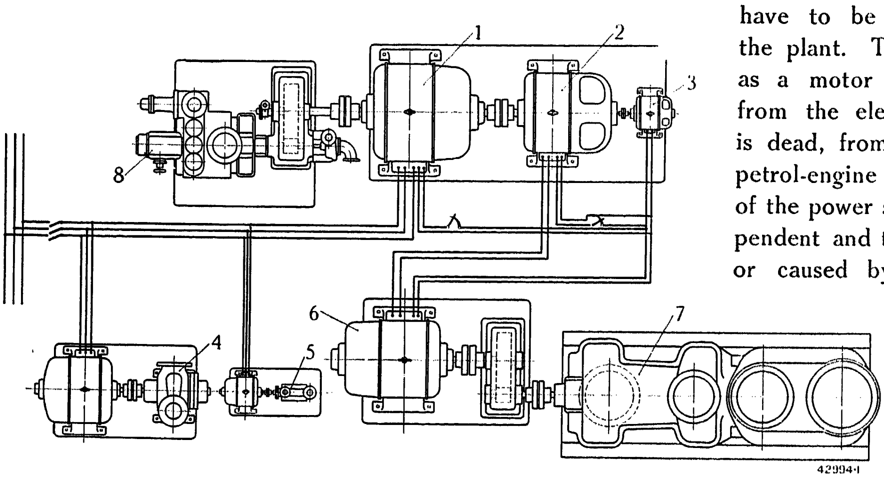


Fig. 10. — Diagram of the auxiliaries of a Velox steam generator.

The auxiliaries are driven electrically from the system because there is no way in which the exhaust from an auxiliary turbine could be used. A stand-by steam turbine takes over the load automatically if trouble occurs on the electric supply system. The synchronous motor of the Ward-Leonard set cuts itself out automatically from the system and runs as a generator supplying the other auxiliaries with current. Trouble on the electric system or in the station cannot affect the working of the Velox.

1. Three-phase synchronous motor. 2. Ward-Leonard generator. 3. Exciter. 4. Circulating pump. 5. Fuel pump. 6. Ward-Leonard motor. 7. Charging set. 8. Stand-by steam turbine.

The drive of the auxiliaries of a Velox which has no steam turbine with it, is carried out differently. The auxiliaries of the condensing plant are of course eliminated. The drive of the auxiliaries of the Velox proper must be by electricity, under usual conditions, because their is no possibility of leading the exhaust from an auxiliary turbine to some stage to a main turbine or to a condenser, or to utilize it in any other way. The arrangement of the auxiliaries given in Fig. 10 shows that it is, nevertheless, possible to make the drive independent of trouble on the electric system. The Ward-Leonard generator, its exciter, the Velox feed pump and the governing-oil pump are driven in common from the electric system by a three-phase synchronous motor, while the circulation pump and the fuel pump are also

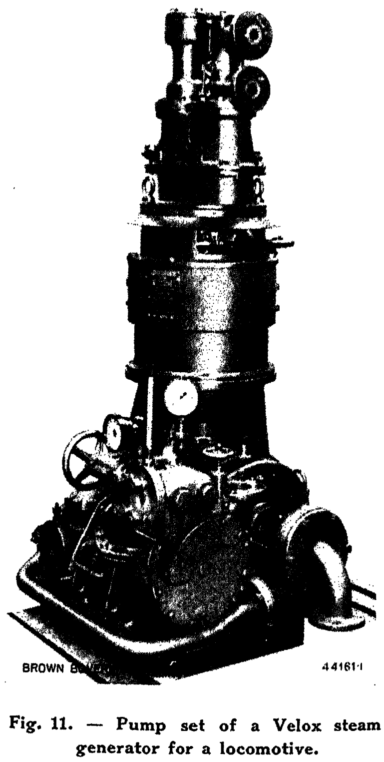


Fig. 11. — Pump set of a Velox steam generator for a locomotive.

A steam turbine drives the following auxiliaries:— Velox feed-water pump, circulation pump, fuel pump, governing and lubricating oil pump, a D. C. generator for the starting of the pump set. This generator also serves to light the locomotive when running.

driven from this source, but separately by induction motors. A spare steam turbine is also built on to the Ward-Leonard set which takes over duty automatically if a disturbance occurs on the electric supply. This turbine is allowed to exhaust to atmosphere or to the feed-water tank during the usually short time it runs.

The synchronous motor cuts itself out, automatically when voltage fails; however, it goes on running as a generator and drives the motors of the circulation and fuel pumps. Thus, in this case as well, trouble on the electric supply or in the power house does not influence the working of the Velox.

Fig. 11 shows the pump set of a Velox plant designed for a locomotive. The driving steam turbines, the Velox feed pump and the low-placed circulating pump, the governing-oil and fuel pumps as well as a D. C. generator and reduction gear are all exceptionally compact in design but, nevertheless, very accessible. The D. C. dynamo is used as a motor to start the pump set and operates, in running service, as a generator to supply the lighting and to drive various auxiliaries.

2. *The Velox steam generator.*

Up to date, Brown Boveri and their concessionary companies have built, or have in hand, 46 Velox steam generators. All these units were tested before despatch and many have been in continuous service now for a period of several years. Much valuable experience has been collected in a relatively short time and put to good use, and we are, thus, able—after a period of development of hardly four years duration — to assert that the Velox is just as reliable in service as the best boilers of older types. Observations made, up till now, show that, if the Velox is properly handled, no recurring service stoppages and repair work — apart from the standard overhauling and cleaning operations — are called for, which makes the Velox superior to the former bricked-in boilers.

The Velox has, really, the characteristics of a machine and it can be expected to work just as reliably as the steam turbine it supplies.

Naturally, this quite novel type of machine, with no antecedents, passed through a period of growing pains. We are happy to be able to state here, however, that there have been no difficulties, whatsoever, encountered which may be imputed to the working principle proper on which the Velox is based. All the following characteristics of the Velox have given brilliant proof of their qualities:— Combustion under pressure and in a small space with a calorific production per cubic metre of combustion chamber about 20 times greater than in other boilers, high gas velocities giving a 15 times better heat transmission through the heating surfaces of the gas tubes, much better evaporation with a minimum of water chamber volume, separation of the big volumes of steam produced from the circulating boiler water, the gas turbine, the axial compressor, the regulating principle of firing and air delivery, the pressure regulation, the feed-water supply, etc. The first plants delivered showed that the Velox principle was a really new factor to be reckoned with in the technique of steam generation. The Velox designers have been quick to recognize and remedy those difficulties of other natures which only became apparent once Velox plants were running in practical service.

We wish to express, here, our grateful appreciation to our clients and to their service engineers for their most efficient collaboration with us, which contributed in no small degree to the elimination of imperfections in the first Velox plants and, thus, generally speaking, helped to increase existing knowledge in the field of practical steam generation.

Now that the Velox has become a very reliable steam generator, it will interest our readers to learn something of the practical experience gained in Velox plants. We will not hesitate to speak openly of the difficulties encountered and how they were surmounted, because we feel that the confidence placed by readers in our technical achievements and general reliability of our products can only be strengthened by a clear statement of facts.

One of the conditions of economic operation and general success of the Velox is a high efficiency of the charging blower with its gas turbine, because the blower output necessary for the high combustion pressure generated amounts to as much as 25—30 % of the effective power to be obtained from the steam generated in the Velox. Fortunately, all the elements requisite to efficient *gas-turbine design* were already available, the Brown Boveri reaction blading with its very high efficiency, as used in our turbines, could be utilized, here. The *charging blower*, however, had to be created in accordance with the latest data available in the field of aerodynamics, and after many tests. The quite new machine developed, the axial compressor, with its inherent sensitiveness of air flow along the wing profile were the cause of the compressor characteristic not coinciding as exactly as was desirable with the resistance characteristic of the gas cycle of the Velox, which was, itself, a rather undetermined quantity, at that time. Thus, there were certain zones of service output where instability in charging was met with. The fault was soon corrected by modification of the compressor blading and it was found possible to so increase the efficiency of the compressor that, to-day, there are certain plants where the charging set not only does not consume power but, actually, gives power back to the electric supply system.

We have been granted patents in most countries covering the use of the axial blower in conjunction with combustion processes under pressure. These were based on our knowledge of the characteristics of the said blower and its particular adaptation to the different organs of which a Velox is composed.

The *Velox-burner* was one of the most difficult problems of all to solve. Up to ten times the usual amount of oil had to be burnt by a *single* burner, in a very small chamber. Further, the oil supply had to be regulated, automatically, from full to no

load, a duty impossible to an ordinary burner. The desired conditions were met thanks to the investigations carried out on the first test Velox we built. There was, sometimes, a very little smoke emitted by the Velox which fault was immediately remedied by slight adjustments of the supply of fuel oil and charging-air volume.

To-day, under rapid fluctuations of load, the Velox run without any production of smoke, a valuable quality for urban plants and for naval vessels.

Those ignorant of the subject have been inclined to consider the *evaporating elements* of the Velox as being a weak point in the design because heat transmission through the walls of these tubes is 15 greater than in former boilers. However, thanks to the forced circulation of the boiler water, the temperature of the walls of these tubes is not higher than that of the walls of ordinary fire tubes and they have shown that they can stand up to years of service, without a weakness developing. This, of course, assumes that the *Velox feed water* has the usual qualities of good water for all high-capacity boilers. Experience has brought to light the interesting fact that the strong flow in the Velox, the energetic movement of the water itself due to great evaporation are factors which prevent, to a considerable degree, the formation and crystalisation of hard scale on the heating surfaces.

Some of the first Velox boilers, which were fed with improperly treated feed water, showed that the wall surfaces subjected to vigorous flow remained clean and that only a few dead ends suffered from scale formation and hot zones. If the feed water is properly treated this kind of trouble is eliminated. Further, improved water circulation caused dead ends to be efficiently scoured and this made the Velox all the more insensitive to feed water which, for any reason, has not been perfectly treated. An interesting fact noted was that tube bursts occurring in one of the first Velox by improper water being used proved harmless in the closed combustion chamber and were hardly noticed, a clear proof of the quality of the pressure-fired steam generator.

A Velox working in the power station of a chemical works showed how adaptable this steam generator can be made to undesirable feedwater conditions. In this plant, all the steam generated is used for chemical purposes, and the feed water has to be constantly renewed from treated raw water, which contains silica and is also a soft river water which sometimes holds in suspension a very fine clay sludge. The water is treated with a solution of caustic soda and magnesium sulphate to soften it; it is then treated with trisodium phosphate. This latter treatment protects the boiler tubes from

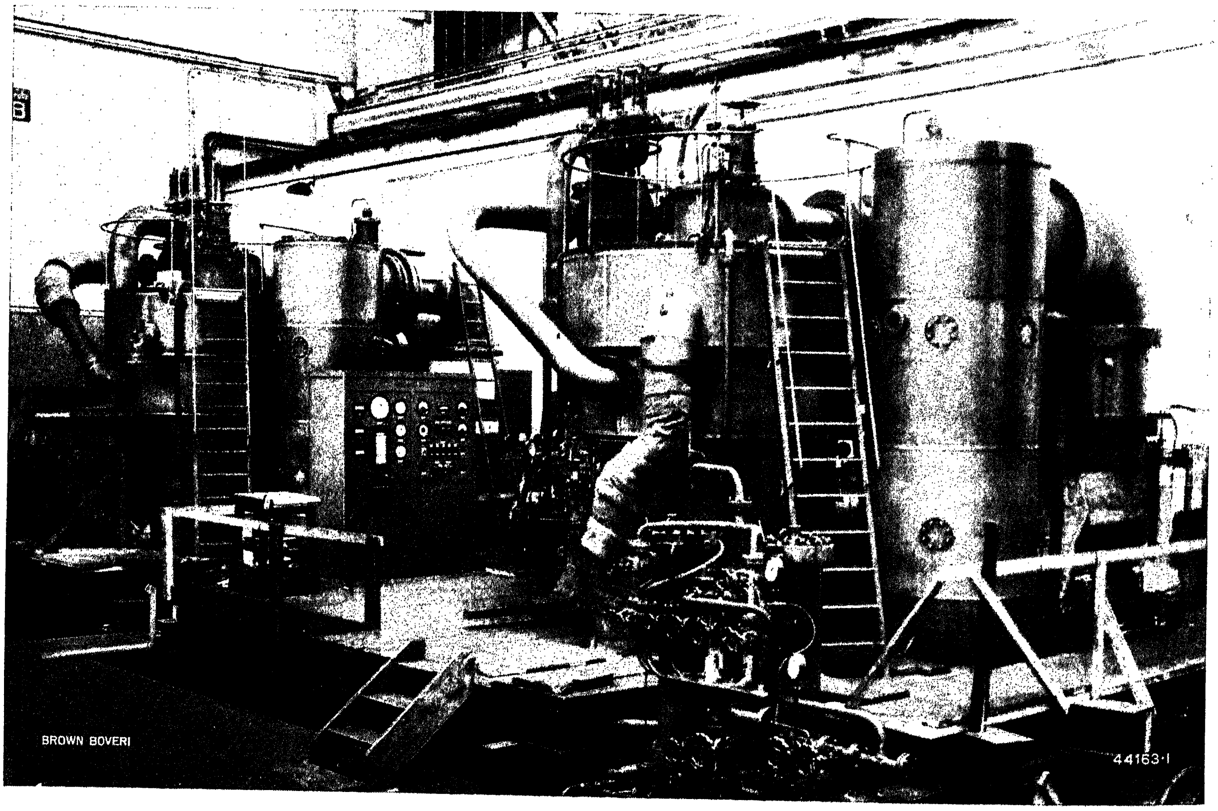


Fig. 12. — Two Velox steam generators, for 45 t/h of steam at 30 kg/cm² and 420° C, for the Wellington Power Station, New Zealand, mounted on the Baden test bed.

The Velox units are mounted with all their instruments and apparatus. They were tested up to overload. Between the boilers, the switchboard is seen, from which all motors and apparatus are remote-controlled by push buttons. A filtering, preheating and circulating equipment for the fuel oil is seen in the foreground.

TABLE I.

Tests on a 45-t/h Velox steam generator for Wellington (New Zealand)

(17th November 1936).

Test	No. 4	1	5	2	3
Load . . . . %	118	105	78	54	31
Steam					
Quantity . . kg/h	48,252	43,119	31,941	22,209	12,922
Pressure . kg/cm^2 abs	18·0	17·4	16·8	17·3	16·8
Temperature . °C	336	332	313	313·6	298·4
Feed water inlet temperature . °C	50·6	50	50·6	48·5	52
Fuel	Shell fuel oil				
Calorific value Hu . . . kcal/kg	—	—	9735	—	—
Temperature before burner . °C	97	103	104	102	103
Quantity of fuel used . . . . kg/h	3595	3215	2340	1638	940
Quantity of air used . . . . kg/h	57,665	50,085	37,450	27,537	18,040
Excess of air kg/h	1·12	1·085	1·12	1·175	1·34
Quantity of hot gases . . . kg/h	61,260	53,300	39,800	29,175	18,980
Auxiliaries					
Ward-Leonard set . . . . kW	−96·2	−126·2	−72·5	−19·7	+18·6
Circulation pump . . . kW	62·9	63·5	65·1	67·8	69·5
Fuel pump . kW	7·5	7·0	7·8	7·8	8·0
Total power input to auxiliaries . . .	—	—	0·4	55·9	96·2
Power restitution to system in . . kW	25·8	55·6	—	—	—
Temperature of exhaust gases °C	107	104	93	88·6	81·6
Plant efficiency:— η of plant =	$\frac{\text{Heat in steam-preheating of fuel} - 4000 \times \Sigma \text{ auxiliary output}}{\text{quantity of fuel} \times \text{lowest cal. value}}$				
Heat in steam 10^3 kcal/h	33,400	29,800	27,780	15,180	8675
Preheating of fuel 10^3 kcal/h	141	134	124	67	41
Heat value of auxiliary output 10^3kcal/h	−103	−222	15	224	385
Useful heat 10^3kcal/h	33,362	29,887	21,655	14,889	8250
Brought in in the fuel . . 10^3 kcal/h	35,000	31,280	22,820	15,945	9150
η of plant . . %	95·2	95·6	95·0	93·4	90·2
Humidity of saturated steam . %	0·43	0·43	0·4	0·45	—

the formation of a silica scale. This Velox has been in satisfactory operation for about a year under these exceptionally difficult conditions of feed-water supply. A second unit has now been ordered by the same clients.

We lay down no special specification as regards the *fuel* used, when we deliver our Velox plants, because we think every oil on the market can be used. However, we were informed of certain difficulties which arose, in different plants, and which are imputable to the quality of the fuel oil used.

Thus, in one case, the feed-water preheater was getting choked up after a new kind of fuel oil had been introduced, and this meant a weekly cleaning of the preheater. The cause was found to be too much sulphur in the oil which was precipitated as a sulphurous acid at low feed-water temperatures and which was then deposited in the gas tubes along with the water vapour and exhaust gas ashes. By slightly increasing the temperature of the feed water, this deposit no longer took place. Further, it was found that the preheaters could be perfectly cleaned simply by rinsing them with water, an easy and brief operation. This led to a layout of the preheaters such as shown in Fig. 12 which allows of simply taking off a cover to get at and clean them.

If the fuel oil has much sulphur, it may happen that the rolled and welded joints of the preheater are attacked by the sulphur. This is prevented by some slight alterations in the design.

The *circulation pump* was a new element of Velox design, the glands of which, contrary to those

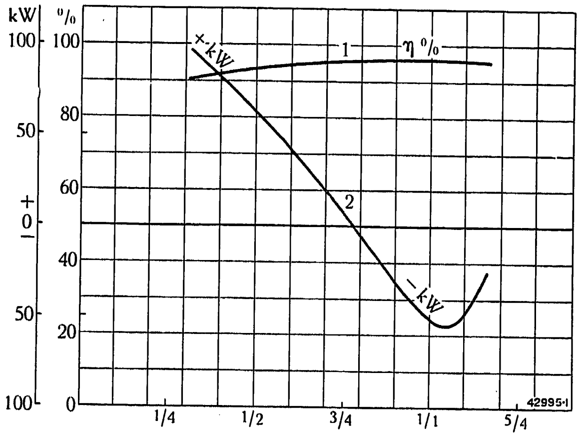


Fig. 13. — Efficiency curve in function of load of the Wellington Velox steam generator, all auxiliaries included, without feed-water pump.

The efficiency is exceptionally good down to 1/4 load which compensates greatly for the higher cost of fuel oil as compared to that of coal.

1. Efficiency.
2. Output of the auxiliaries (without feed-water pump) either taken from or restituted to the electric supply system.

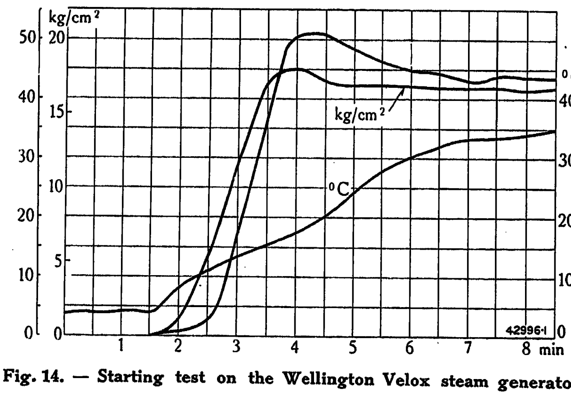


Fig. 14. — Starting test on the Wellington Velox steam generator.

From standstill and cold state up to full load of steam in 3½ min. The slow rise of steam temperature is beneficial to the turbine.

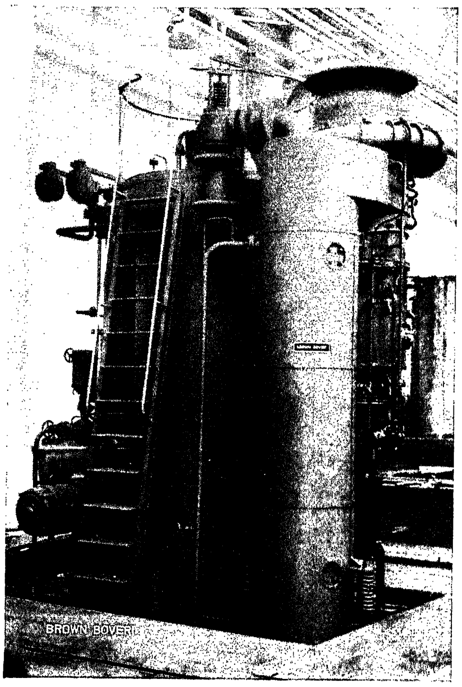


Fig. 15. — Velox steam generator for 9 t/h of steam, 25 kg/cm² abs for Dombowita.

The charging set is vertically mounted in close proximity to the combustion chamber.

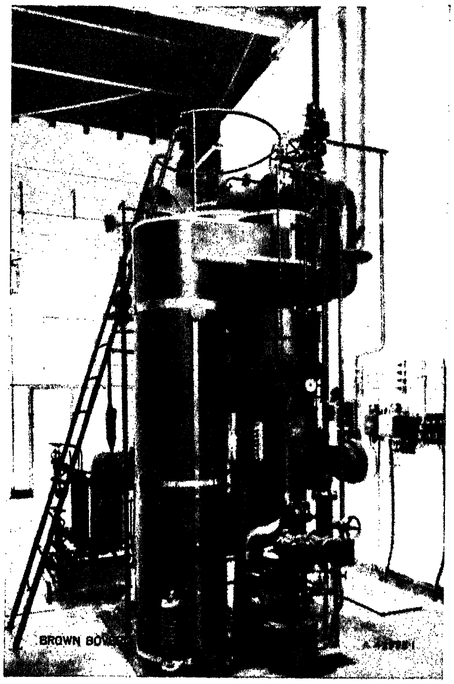


Fig. 16. — High-pressure Velox steam generator for 5 t/h of steam at 80 kg/cm² and 470° C.

We will show in the following pages some illustrations of Velox plants built.

Fig. 12 shows two Velox steam generators on the test bed. These units are for the town of Wellington (New Zealand). They each generate 45 t/h of steam at 30 kg/cm² and 420° C. These Velox were tested and passed by Lloyd and by the Swiss Boiler Association. Table I gives the test results. The remarkably-high efficiency of 95·6% at full load was attained and this includes the power required for all auxiliaries (without the feed pump). Fig. 13 gives the curve of the efficiency in function of the load and shows that, down to quite low loads, the efficiency is far higher than any figures previously reached. This economic quality of the Velox is the more valuable for plant in continual operation under fluctuating loads; this is also so for peak-load plants and heating plants which must work with oil in order not to produce smoke or because there is little space available. The starting up tests on these two Velox also gave astonishing results which are shown in Fig. 14. From stationary cold state, the Velox was brought up to full-load delivery

of a feed pump, have to stand up to the full boiler pressure and full temperature. Despite careful preliminary investigation, this element was the seat of various kinds of trouble, at first. We brought out a new sealing material and modified the pump design proper and the glands, while introducing intensive cooling of the latter; these measures were successful in eliminating the trouble and we have built sealing glands to this new design for pressures up to 80 kg/cm² and 300° C.

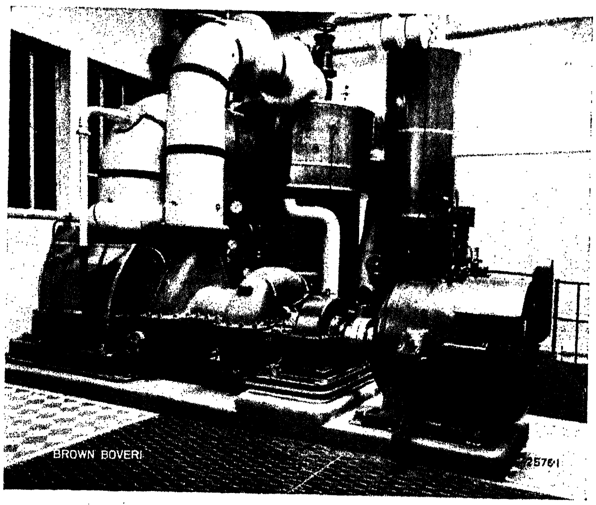


Fig. 17. — Velox steam generator for Blin and Blin, for 16 t/h of steam, 25 kg/cm² abs and 375° C.

All apparatus is governed from the switchboard seen beside the Velox.

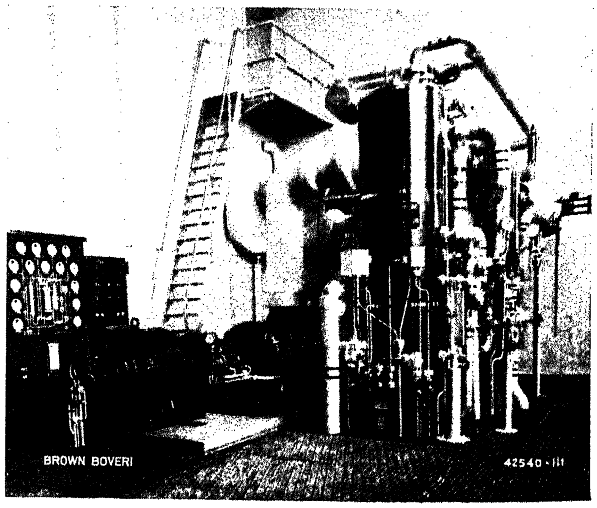


Fig. 18. — Remy plant at Gaillon. A 12-t/h Velox steam generator.

The switchboard, from which all the apparatus can be controlled, is seen beside the Velox.

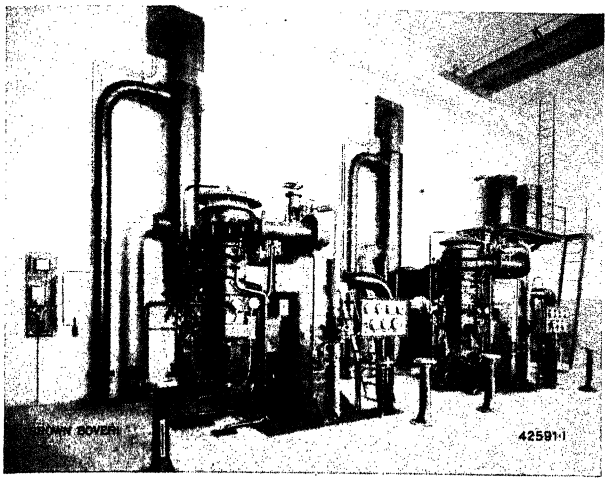


Fig. 19. — Velox remote-heating plant of the Rome Città Universitaria.
Two Velox for hot-water generation and mazout firing, each for 4,000,000 kcal/h, temperature of hot water 80—100° C.

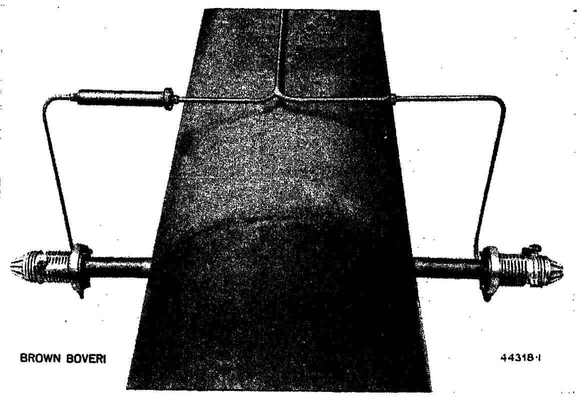


Fig. 21. — Smoke detector to supervise the smoke-free operation of the Velox.
The transparency of the smoke column is measured by an electric lamp and a photographic cell and can be read off an instrument on the switchboard panel. This apparatus can also be delivered for other types of firing, for Diesel engines, etc.

in $3^1/_2$ minutes. This proves how suitable the Velox is for peak and for stand-by plants, which must intervene at short notice.

Figs. 15 shows a small Velox with vertical-shaft charging set (charging blower, gas turbine, auxiliary motor). This vertical set is located close to the combustion chamber. The design, built up to 10 t/h output, has the advantage of being rapidly erected.

Figs. 16 to 19 illustrate some new Velox equipments, showing the compact and pleasing design characteristic of these plants.

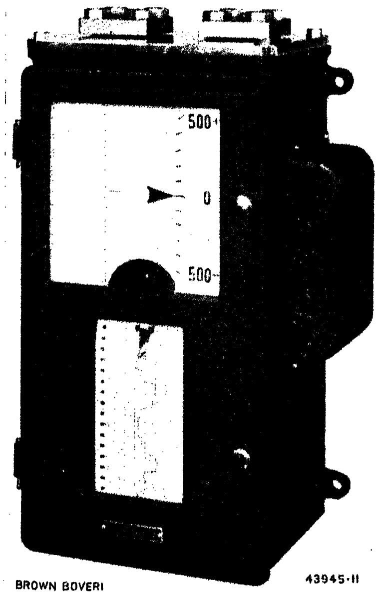


Fig. 20. — Brown Boveri Nivometer.
This boiler water-level indicator can be placed anywhere convenient below the water level. It has end travel contacts actuating an alarm or feed device. The Nivometer is delivered as a second water-level indicator with all Velox plants.

To conclude our report on the Velox steam generator, we desire to mention two interesting apparatuses which can be used on other types of boiler. Fig. 20 shows the *Brown Boveri Nivometer* used on all Velox plants as a second water gauge. It can be placed anywhere below the level of the water in the boiler.

Indications and recording devices are on a large easily-read scale. Electric contacts close in the extreme positions, i. e. when there is too much or too little water. These contacts energize an alarm device or cut out the Velox. The Brown Boveri Nivometer makes use of a mercury column measuring the difference in pressure between a fixed tube connection above the level of the water and the level of the water itself. There are iron balls carried on the mercury which transmit magnetically the displacement of the mercury columns to the indicating device, without any sealing glands being required. This nivometer suits all known types of boiler and, with its alarm device is a welcome addition to the safety appliances.

The *Brown Boveri smoke detector*, Fig. 21, is another interesting apparatus. It is composed of an electric lamp and of a photographic cell placed each on one side of the smoke flue. Both elements are protected from dirt and heat by a current of air from the air compressor. The thickness of smoke is measured by the current of the photo cell and shown on a scale on the switchboard panel. This device allows of supervising the behaviour of the boiler, independently of the light and time of day.

3. *Steam turbines.*

Our firm has done pioneer work in the field of high-pressure steam-turbine development and has created a super *high-pressure high-temperature turbine*, this by a suitable design of the turbine proper and special construction of various important details. As the following Table shows, we have built a large number of high-pressure and high steam temperature turbines and, in so doing, have collected much valuable experience in this field.

TABLE II.

Turbines for	Number	kW
Steam pressure 50— 99 kg/cm³ abs	29	341,000
„ „ 100—200 „ „	14	178,000
Steam temperature 400—500° C	300	2,800,000

Fig. 22 shows the section of a high-pressure turbine, for 100—130 kg/cm² steam pressure and 450—500° C. A characteristic feature of this design are the nozzle boxes which are separately fitted into the *turbine casing* in one piece with the nozzle and welded by a patented process to the turbine housing and also to the adjacent housing of the control valves. The awkward high-pressure flanges, bolts and sealings of the nozzle chests and steam inlet connections are eliminated by this welding, as Fig. 23 shows clearly.

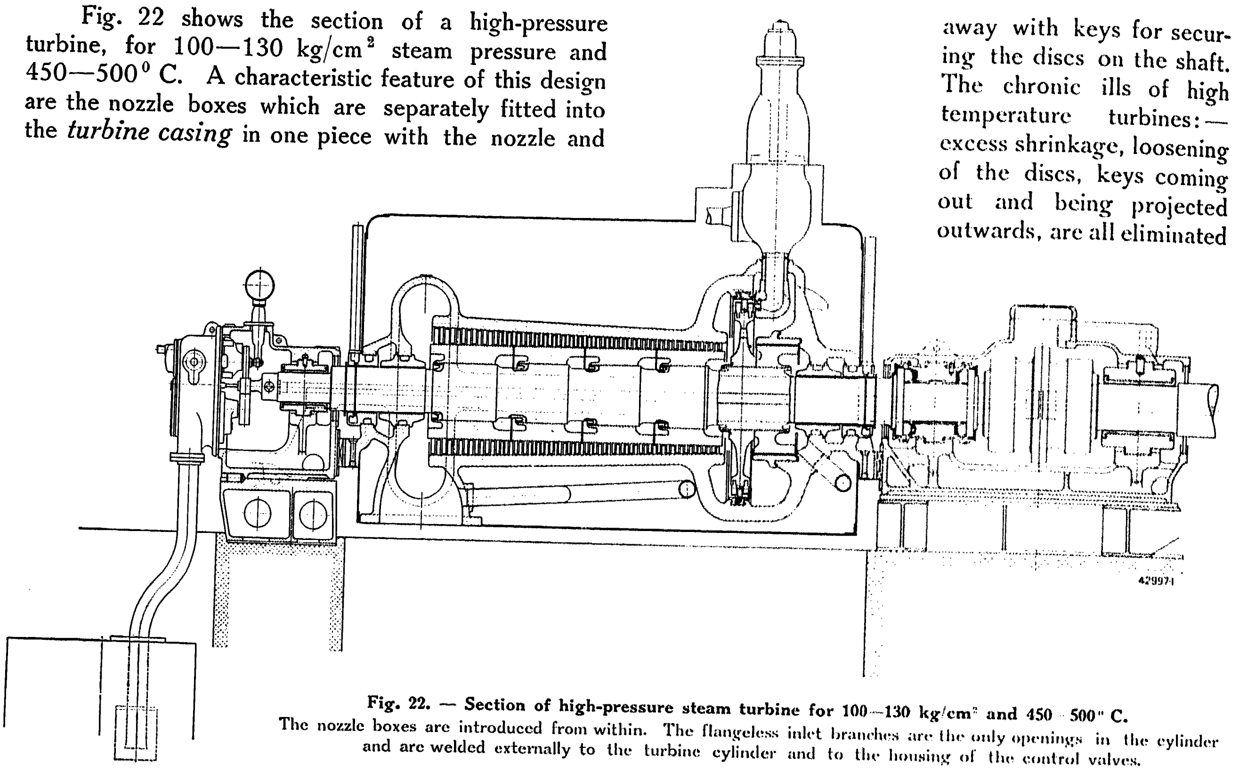


Fig. 22. — Section of high-pressure steam turbine for 100—130 kg/cm² and 450—500° C.
The nozzle boxes are introduced from within. The flangeless inlet branches are the only openings in the cylinder and are welded externally to the turbine cylinder and to the housing of the control valves.

The nozzle chests, built of high-temperature proof material, are alone subjected to the superheated steam, while the housing of the turbine with its separating flange has lower temperatures and pressures to stand up to. The wall of the cylinder of the high-pressure part is only pierced by the small, flangeless apertures to take the nozzle chests; it is thus, practically, whole as compared to the usual design in which the high-pressure cylinder is cut to allow the lodging of the nozzle chests. On account of the high temperatures of the housing, the turbine rests, quite free, on low and strongly-built feet or paws on the cold bearing pedestals. There are cross keys in the paws at the high-pressure end and guiding keys in the middle plane, which maintain it rigidly in axial sense but allow it to expand or retract freely in both lateral senses and longitudinally. The feet or paws are very low which excludes a displacement of the axis of the housing in the vertical sense.

The *turbine rotor* is specially designed for high temperatures. It is small, and not too massive in any part so that it heats up rapidly and uniformly at the starting up of the turbine and can follow, immediately, the temperature changes inherent to load fluctuations. The discs and balancing pistons of the high-temperature zone are welded to the shaft by means of flexible cylindrical prolongations on the said discs, this being a patented process which does away with keys for securing the discs on the shaft. The chronic ills of high temperature turbines: — excess shrinkage, loosening of the discs, keys coming out and being projected outwards, are all eliminated in the welded Brown Boveri rotor. The welded rotor design has, already, been used on about 80 steam turbines and about 300 gas turbines and has given most satisfying results.

The *governing gear* calls for very careful study in turbines of this class. There are considerable forces set up by the high steam pressures, which are incompletely balanced and which act on the valves and there are also considerable heat expansions resulting from the high temperatures as well as undesirable friction conditions in the spindle guides to be reckoned with. Gripping and friction can be

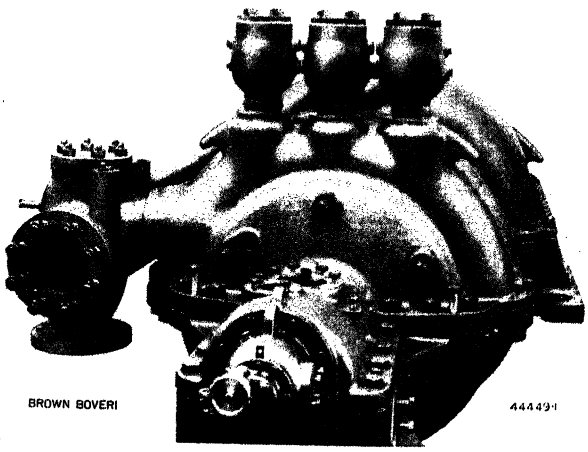


Fig. 23. — Superheated steam turbine for 450—500° C.
The nozzle chests and governing-valve housing belonging thereto are welded to the turbine cylinder, by a patented process. There are no flanges, bolts, glands on the nozzle chests or on their steam inlet pipes. This is very advantageous for high pressures.

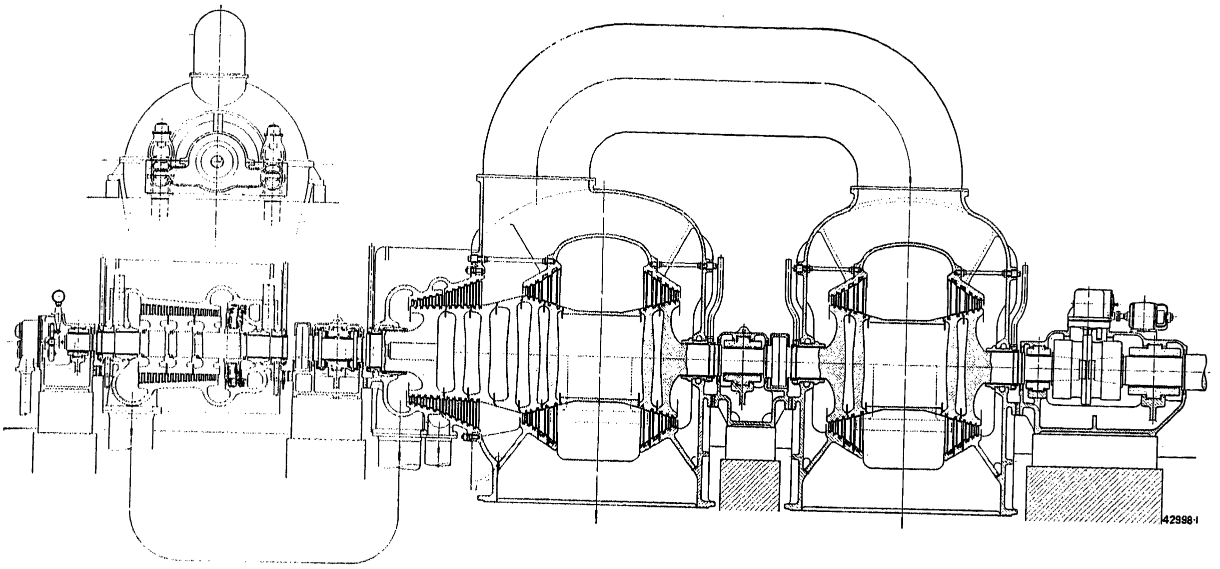


Fig. 24. — Brown Boveri big turbine for outputs up to 100,000 kW and pressures up to 80 kg/cm² and 450° C.
The rotors are welded and adapt themselves flexibly and rapidly to all temperature fluctuations at starting and in service. The big volume of steam requires four parallel steam exhaust channels.

dealt with by using special valve designs and suitable material. Further, the high-pressure high steam-temperature turbines have auxiliary servo-motor governing (turbine governor regulating small oil-pressure servo-motor which governs in its turn the powerful servo-motor for the valves). Big forces are, thus, generated to move the valves and reliable governing movements are assured even at 500° C.

These turbines allow of utilizing the highest steam temperatures in absolute safety and thus meet the Carnot requirement:— introduction of heat to the cycle at highest possible temperature. We have, therefore, called this type of turbine the "Carnot turbine".

High-pressure steam at a high temperature is used in order to attain high efficiency in the cycle process and thus to reach a low fuel-consumption figure for the steam plant. It is, therefore, natural that the designer should also strive to attain the *highest possible turbine efficiency.* Brown Boveri uses, to this end, *impulse blading* for the first stages, because, even at partial loads, it gives good efficiencies, by partial nozzle admission. In all the remaining part of the turbine, however, the patented Brown Boveri *reaction blading* is used, the efficiency of which is 95 % and which allows of attaining the highest possible economy of the plant.

A turbine of high efficiency for a big heat drop requires a relatively large number of blade stages and this makes a subdivision into several cylinders necessary. This subdivision has the great advantage that, at starting and when sudden load changes occur, the high-temperature part is absolutely separated, in a small high-pressure cylinder, from the rest of the turbine, which is colder. Further this design has the advantage that the axial thrusts of the shafts can be compensated by counter action of different sections of the blading which allows of eliminating balancing pistons with the losses inherent thereto.

Fig. 24 gives the section of a big turbine, which is suitable for outputs up to 100,000 kW and pres-

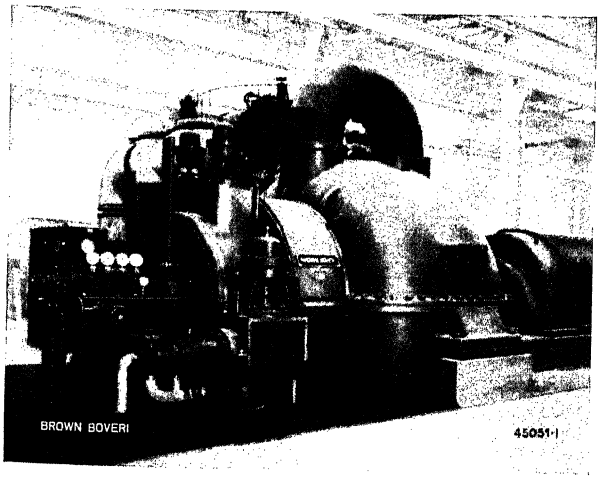


Fig. 25. — View of 32,000-kW single-cylinder/steam turbine, 3000 r.p.m. for the Oslo Power Station, having two, parallel steam exhausts.

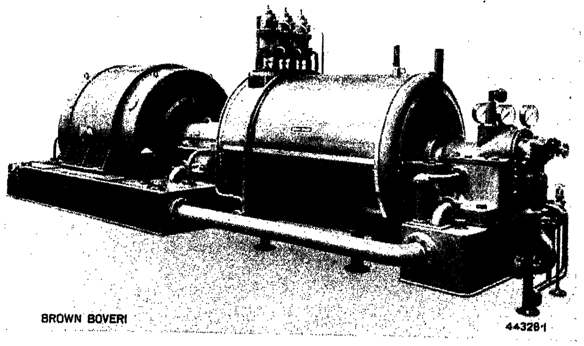


Fig. 26. — Back pressure turbine, 1250 kW, 46 kg/cm² abs, 450° C. and 7·5 kg/cm² abs back pressure.
The steam for heating is first used to generate electricity. The unit runs in parallel with an electricity distribution system.

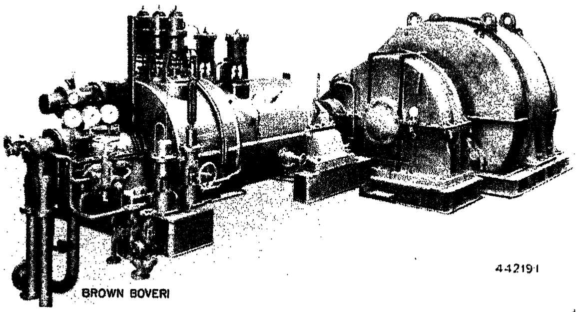


Fig. 27. — Extraction turbine for 3320 kW, 6000 r. p. m.

The set supplies a British cardboard factory with electricity and hot steam which, however, first does work in the high-pressure section of the turbine before being utilized. Both high and low pressure sections of the turbine are governed by nozzles.

sures up to 80 kg/cm^2. We chose a speed of 3000 r. p. m. for this big output, because experience shows clearly that these high-speed units at high steam pressures and temperatures are not only cheaper and smaller but are less sensitive to changes in temperature, owing to their smaller size, and are, thus, more reliable in service. Fig. 24 shows that the rotors are welded and material saved in this way. The big volume of exhaust steam calls for four low-pressure blading sections in parallel. The three bearing pedestals rest, directly, on the foundations and also carry the cylinder with its supporting paws. The axial displacement of the blading is equalized through the supporting paws and the coupling, by a patented process.

In stand-by plants, only running for a short time, efficiency plays a less important part while low first costs come to the fore. For this reason, we have often used single-cylinder turbines, which are cheaper and call for lower building costs for the engine house as they take up less room than multi-cylinder units. Fig. 25 shows the 32,000-kW single-cylinder unit at 3000 r. p. m. for the Oslo Electricity Works, chosen here, chiefly, because of the restricted space available.

Fig. 26 shows an industrial turbine of the back-pressure type and Fig. 27 an extraction turbine with nozzle-valve governing both on the high and low-pressure ends.

New demands have been made on steam-turbine *governing* owing to the linking up of big power stations to extensive distribution systems. A generator unit, alone on a consumer system, always gives the output required of it, its speed and frequency varying slightly according to the governor characteristic (speed n in function of output L). If the said curve is a straight line, i. e. if $\frac{dn}{dL}$ = constant, the speed variation for a given load variation, at every load, will be the same. If the said curve deviates from the straight, the change in frequency for a given change in the load will differ according to the inclination of the curve. If, now, there are several machines of the same power house, or on the same system, connected in parallel, the speeds of all the machines will change, when the load on the system varies, according to the sum of all the regulating characteristics. If all regulating curves were the same inclined straight lines, the load ratios of all the machines would be the same. If the curves deviate from one another the load repartitions change according to the value $\frac{dn}{dL}$.

This shifting of load between the respective turbines is without importance as long as the units are in the same station, as the station operator can intervene and make suitable adjustments. It is a much more difficult problem when, in the place of several machines in one station, there are several power stations or, even, several independent electricity companies with interconnected power stations. In such cases the load is devided up between them according to contracts in accordance with their power and the price of the electrical unit. For instance, it may be agreed that all stations share equally in current delivery or else there may be hydraulic plants with peak-load storage plants or steam power stations the current of which is expensive and which should, thus, only be called on when the ordinary hydraulic power stations are fully loaded.

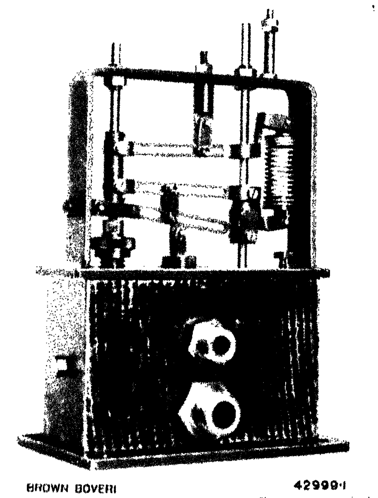


Fig. 28. Load-carrying apparatus for Brown Boveri steam turbines.

This apparatus allows of altering the governor characteristic curve of the turbine, during operation, from a rising to a falling curve, passing through the isodrome characteristic. The capacity of the turbine to take over load can, thus, be made to obey the load program desired, over a wide range.

The carrying out of a determined loading program or chart is much simplified if a simple means can be found to alter the inclination of the governor characteristic and, therewith, the capacity of the machines to take over load. To meet these requirements, Brown Boveri has brought out a *load-carrying apparatus* which can be built on to standard Brown Boveri steam-turbine governing gear, at little cost. It is shown (cover removed) in Fig. 28. The apparatus allows of altering the speed/load characteristic of the turbine over a wide range, from a rising governor characteristic through the isodrome characteristic to a falling governor characteristic, this when the unit is operating, and thus of varying the capacity of the said unit to take load, in such a way that it meets the loading programme or chart laid down.

The device also allows of varying the momentary and passing irregularities of the governing system and thus of avoiding hunting.

4. *Condensing plants.*

The Brown Boveri condenser, in its latest design, can be said to have reached a development stage

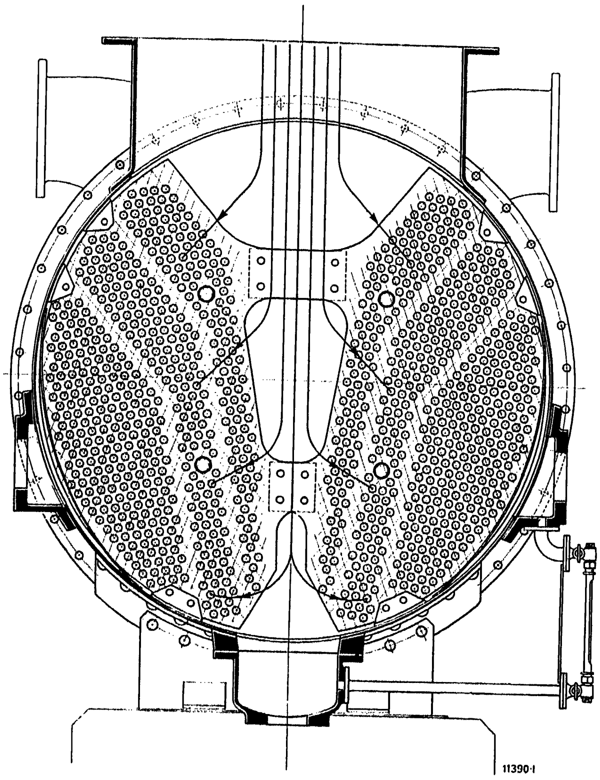


Fig. 29. — The OV-type of condenser which Brown Boveri has been building for 25 years.

The steam flows from a wide central passage to two lateral stacks of water tubes, the section for steam inlet being big and the depth of the stacks small.

which makes it an apparatus offering every guarantee of reliability. We would recall, here, that the condenser tubes are arranged in the shell in the so-termed OV form (Fig. 29), in which the steam flows to the two lateral sheaves of condenser tubes through a V-shaped inlet channel extending the whole length of the shell which offers big open surfaces to the lateral flow of steam between the tubes and little depth, therefore little resistance, of the tube stacks. This design, created by us in 1911, is so suitable to condenser operation that, as soon as our patent rights on it had lapsed, a number of other firms took it up. Thus, it will be found on the new Cunarder-White Star liner "Queen Mary". Our design of condenser with double water chamber, allowing of cleaning in service, has also become common property, to-day. The design proper to the new Brown Boveri condenser is shown in Fig. 30. The tubes are expanded at both ends into the tube plates. According to a patented process, they are first given a wavy shape, and, at the points of contraflexion, they are supported by stiffening plates, in order to prevent deleterious stressing between the tubes and the shell or between tubes in different positions, when temperature differences arise. The tightness of the tube

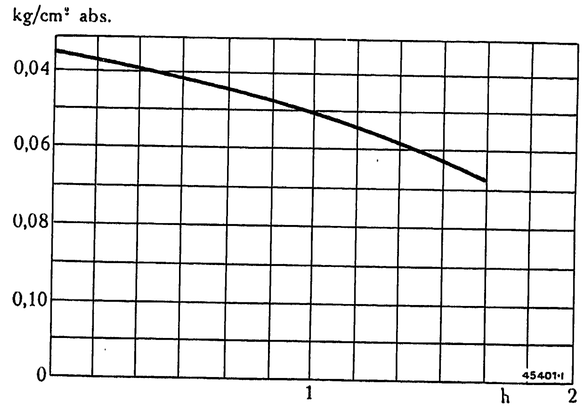


Fig. 31. — Vacuum characteristic of a 16,000-kW Brown Boveri steam turbine plant with vacuum pump shut down.

The plant can work for hours without the vacuum pump, without endangering service.

fittings is no longer dependent on hundreds of glands which sooner or later become loose, especially when there is an insufficiency of water. Further, the brass of the tubes no longer requires to be hard, in order to prevent the tubes being squeezed into the glands, as used to be the case. Soft brass tubes are, now, used with this expanded process and these have the great advantage of being subjected to hardly any corrosion and of bursting very rarely indeed.

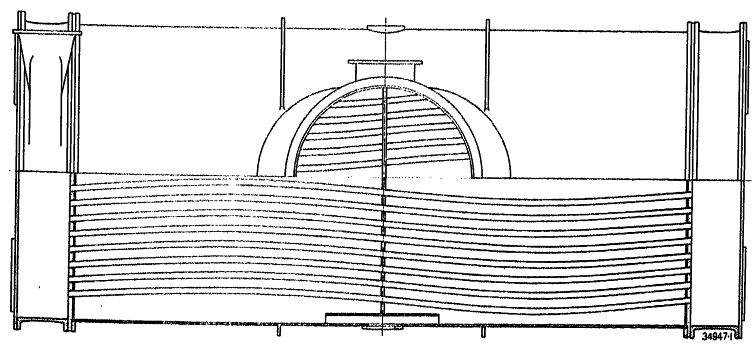


Fig. 30. — Brown Boveri condenser with wave-shaped tubes.

The cooling tubes are expanded into the shell end plates at both ends but are given a wavy shape before being put in, to prevent undesirable stressed due to temperature inequalities between tubes and between tubes and shell (patented). The tubes are supported at the point of contraflexion. The elimination of sealing glands makes the condenser very tight. The tubes can be of soft brass and are, thus, less susceptible to corrosion.

The Brown Boveri condensers with wave-shaped tubes are being built to-day, under licence, by several other firms, for stationary plants as well as for merchant and naval vessels.

The vacuum chamber of the condenser has no flange towards the outside, through which air could filter in, apart from the unavoidable pipe connections

for steam inlet and the air and condensate-suction outlets. Our condenser plants are, really, so tight, on this account, that service can be kept up for hours without running the air ejector pump. Fig. 31 gives the results of a test on a 16,000-kW steam-turbine plant which ran for two hours with the air ejector pump cut out, without any troublesome deterioration of the vacuum occurring.

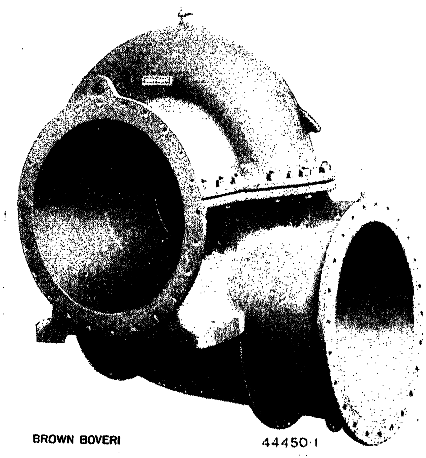


Fig. 32. — Housing of the new cooling-water pump for condensing plants with high-speed motor; for large quantities of water under low heads.
For cleaning purposes, it is easy to remove the cover.

Fig. 32 shows the latest cooling-water pump design for relatively big volumes of water and low heads. The pump is very compact. The branches are so laid out that the big cooling water pipes can be arranged simply and suitably. The cover of the pump is easily removed without preliminary dismantling of the said pipes. This requirement is generally specified by steam-power house operating engineers, because the cooling-water pump often has to handle very dirty water and provision has to be made for cleaning it with as little difficulty as possible.

5. *Turbo-generators.*

The demand for electric power, which increased by leaps and bounds in the years just after the War, obliged power-generating stations to make exceptional demands on the resources of manufacturers and this, particularly, as regards the two-pole type of turbo-generator, by the forcing up of the individual outputs of these machines. It is only just to say, here, that these requirements met with a courageous response both from electrical and the metallurgical firms concerned.

If, on the one hand, the increase in output of generating units was met by an increase in the dimensions of the said units, on the other hand, the requirements of economy, which characterized technical developments in recent years, naturally led to the endeavour to attain better utilization of material and introduce simplifications in design.

This better utilization of material was attained by decreasing losses, by introducing better cooling methods combined with considerably lower volumes of cooling air. The superior efficiency, which went hand in hand with these improvements in design, is a factor which is being more appreciated, in recent times, than it was a few years ago, when there was a tendency to assume that capitalization of losses should be disregarded if only low first costs of the plant were achieved.

This progress in design was carried out by careful avoidance of all these constructive factors which experience proved to be the source of losses and also by the introduction of some quite new principles in the elimination of the unavoidable quantity of heat generated in the machine.

As the following Table shows, efficiencies were attained on two 37,500-kVA generators which, up till quite recently, would only have been possible by resorting to artifices such as oil and water cooling or by making some undesirable concessions in the field of the operating reliability of the machines. The results attained approach, in fact, those figures generally associated with oxygen cooling, a design we have never given our approbation to, on account of the complications it means in design and operation and the increased supervision it demands.

TABLE III.

	kW	kW	kW	kW	kW
Output	37,500	30,000	22,500	15,000	7500
Efficiency	%	%	%	%	%
at:— p. f. = 1	98·5	98·4	98·1	97·5	95·6
p. f. = 0·8	—	98·0	97·8	97·3	95·4

A considerable simplification has been introduced in the design of turbo-generators up to 3125 kVA by putting in a single fan wheel, instead of two, on the rotor, this while leaving our well-known cooling system unaltered and, even, improving it to the point that all appreciable differences in temperature in the machine due to differences in the flow of cooling air are entirely eliminated. The new design also offered attractive possibilities to combine the cooler and the generator so that they took up less space, this, however, without lodging the cooler proper in the generator housing, which is not a desirable arrangement.

Turbines for industrial requirements were built for speeds exceeding 3000 r. p. m., in order to enjoy better steam consumption figures, this for low outputs, the generator being driven through a reduction gear. Thus, we built two generators for 1000 r. p. m. each to deliver 3900 kVA and driven by turbines at 6000 r. p. m. These are high-pressure extraction-type turbines for the Warrington Paper Mill, England.

B. DIESEL POWER STATIONS.

The *charging process for Diesel engines, according to the Brown Boveri-Büchi system* is being used, to-day by 42 different firms. Eleven of these, among them Sulzer, MAN, Deutz, Harland & Wolff, hold general licence agreements for themselves and their own licensees. The number of charged Diesel engines had risen to 350 at the end of 1936 (Fig. 33) and the total output of charged engines to 600,000 brake H.P.

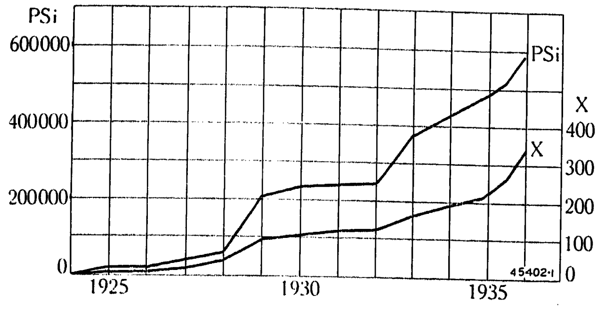


Fig. 33. — Number and output of Brown Boveri Büchi charged Diesel engines.

There was a hold-up of development during the severe industrial crisis which, however, was quickly recovered.

PSi. Total output of charged Diesel engines.
X. Number of charged Diesel engines.

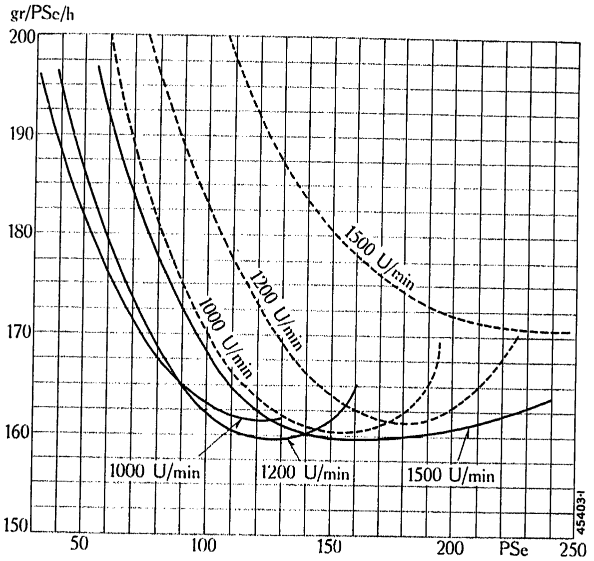


Fig. 34. — Fuel consumption of two Saurer-Diesel engines, 225 H.P., one (dotted line) uncharged, the other (full line) charged.

The great improvement in fuel consumption at high speeds and especially at partial loads will be noted.

We desire to refer, shortly, to the advantages to which, alone, must be attributed the exceptional development of the field of application of the charging process. This is best done in connection with the test results of a charged Diesel engine, reproduced in Fig. 34, and which Messrs. Ad. Saurer A.-G., Arbon (Switzerland) have placed at our disposal. Generally speaking, by means of charging, the output of the Diesel engine can be increased by 50—60 % continuous-load rating this without any major alterations to the said engine except the adding of the charging set. The specific fuel consumption of a low-speed engine at full load is improved by about 5 % and that of a high-speed engine by 10 % as compared to the specific consumptions when there is no charging. At half-load the saving in fuel is 10—20 %. The consumption of lubricating oil remains the same, despite the addition of charging; it, therefore, diminishes as measured per H. P. delivered. The space taken up is hardly any greater as is clearly shown by Fig. 35 of a MAN charged engine; the weight is only very slightly greater. The running of the charged engine is smoother, because the combustion is less violent due to the scavenging and because the exhaust gases of the engine flow to the gas turbine and give up to the said turbine the power they contain. Regulation is very good as the charging set adapts itself, rapidly, to all variations in load.

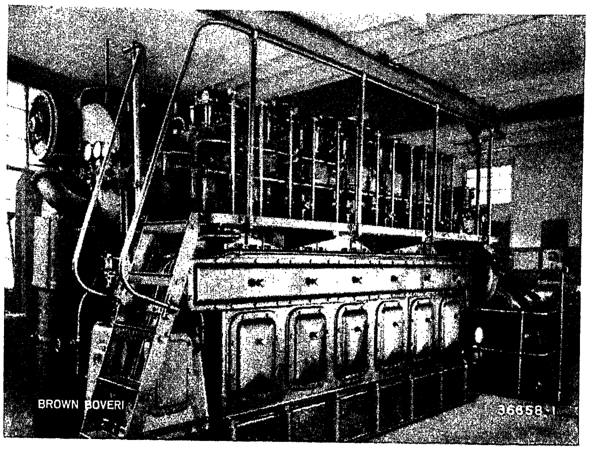


Fig. 36. — Sulzer-Diesel engine at 375 r.p.m. dating from thea yer 1932 and placed in the Jakob Rieter Maschinenfabrik in Winterthur (Switzerland). By adding a Brown Boveri-Buchi charging set its output was raised from 390 H.P. to 550 H.P. and its specific fuel consumption lowered to 163·5 g/H.P.

An interesting field, full of possibilities, is that of the *placing of charging sets* on existing Diesel engines, so as to increase their output and bring down their specific fuel consumption. Fig. 36 shows a four-stroke Diesel engine in the Jakob Rieter Machine Works in Winterthur (Switzerland), built in 1932, the output of which has been increased by the addition of a Brown Boveri charging set built by Messrs. Sulzer Bros., from 390 H. P. to 550 H. P.

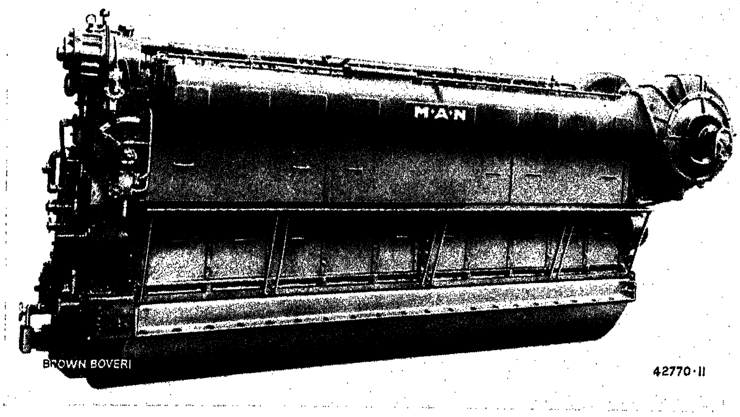


Fig. 35. — MAN Diesel engine charged to 1750 H.P.

The charging blower is incorporated in the design of the engine. It increases its output by 50 % but does not take up any additional space.

In this field, a three-phase generator of 875 kVA at 300 r.p.m., 6000 V, 50 cycles, ordered from us, is worthy of note. This unit is driven by a Diesel engine through a magnetic coupling combined with the flywheel. When disengaged, the coupling allows of using the generator as a phase advancer.

C. HYDRAULIC POWER STATIONS.

Since our last year's report, there have been no essential changes to record, in this field. We are expecting a period of inactivity of some duration as regards the building of new hydraulic stations in Switzerland, after the starting-up of the Etzel Power Station, at a near date, to which we delivered both single-phase generators and 150-kV switchgear material. The reason for this is that the demands for power are now amply covered, including all possible requirements for traction, this even if the requirements of industry should show considerable increase in the next few years.

On the other hand, replacement of obsolete turbines in local plants and on small power-transmitting systems offered an opportunity for the replacement of the generators belonging thereto by modern units.

In other countries, where the development of hydraulic power has not nearly attained the degree of completion characteristic of Switzerland, and where big hydraulic developments are still possible, we, as well as our concessionary companies, have been able to participate, most successfully, in the equipment of electric power stations of big and small outputs. The wide experience gathered, in the design of generators for big Swiss power stations, as well as in that of transformers and switchgear, came in usefully here, both for us and our concessionary companies.

1. *Generators.*

A three-phase vertical-shaft generator, for 475 kVA, 750 r.p.m. was built, recently, for the Brugg Power Station (Switzerland). This unit is driven by the turbine through a reduction gear with helical-gear teeth, at a ratio of 1 : 12·7. The same arrangement was carried out for the Aarau Power Station (Switzerland) where a Kaplan-type turbine was put in to replace a former Francis-type unit. This former set was of vertical-shaft design for two-phase current, 1600 kVA, 107 r.p.m., 4200 V, 50 cycles and the new set, also of vertical shaft design, is for three-phase current, 2000 kVA, 107 r.p.m., 8600 V, 50 cycles. The transformation involved replacing the shaft, pole-wheel, exciter, stator winding and upper carrying spider as well as the guiding and carrying bearing. All other parts could be left unchanged despite the increased output and rise in run-away speed from 170 to 275 r.p.m. A three-phase vertical-shaft generator of standard design, built for 1500 kVA, 9500 V, 50 cycles, 125 r.p.m. was built for coupling to a propeller-type turbine in the old Wynau Power Station belonging at the Wynau-Langenthal Electricity Works (Switzerland).

Our concessionary companies have built bigger units than these. Tecnomasio Italiano Brown Boveri built a horizontal-shaft generator for the S.A. Ovesticina-Novara, of 10,000 kVA, 630/750 r.p.m., 10,000 V, 42/50 cycles. This generator is coupled to heavy flywheels (36·2 tm²) which are enclosed in the generator outer casing. They also built two vertical-shaft three-phase generators 11,500 kVA, 675 r.p.m., 10,500 V, 45 cycles with main and auxiliary exciters and an auxiliary generator, for the San Mango sul Calore plant of the Società Meridionale di Elettricità. The said auxiliary generator is used, solely, to supply the motor which drives the governor pendulum of the turbine. Fig. 37

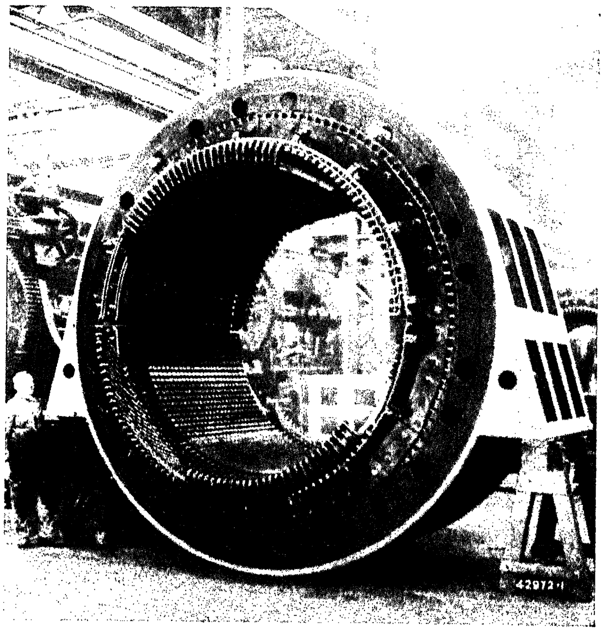


Fig. 37. — Wound stator of the 20,000-kVA generator for the Goglio Power Station of the Società Edison, Milan.

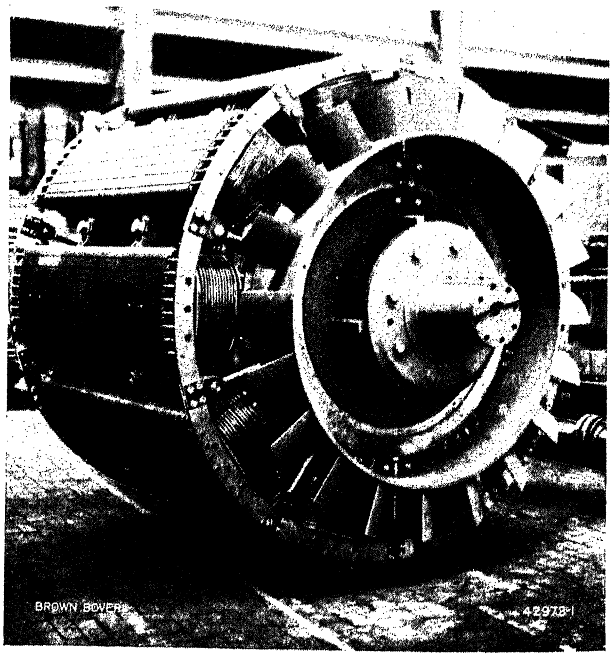


Fig. 38. — Pole wheel of the 20,000-kVA generator for the Goglio Power Station of the Società Edison, Milan.

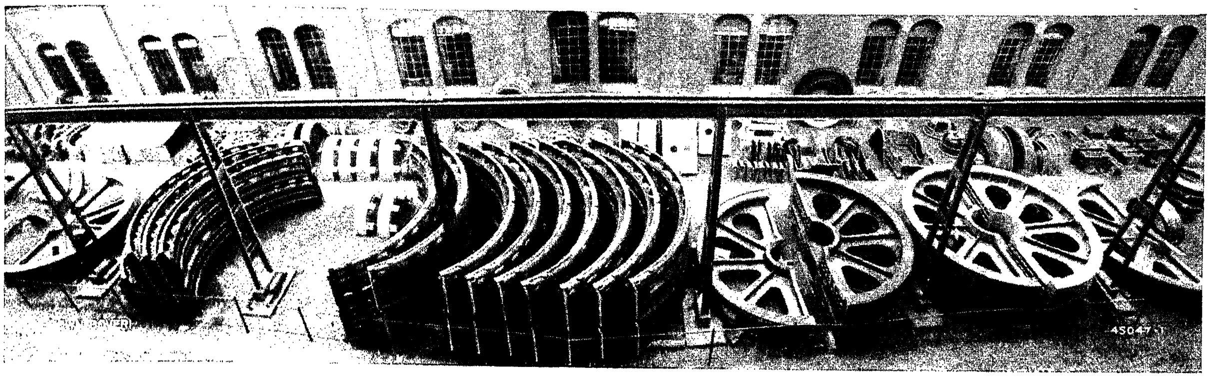


Fig. 39. — Parts of vertical-shaft outdoor generators, 5000 kVA, 115 r. p. m., 6300 V, 50 cycles.

shows the partly-wound stator of the horizontal-shaft generators, 20,000 kVA, mentioned in our last-year's report and built for the Goglio Power Station of the Societa Edison, Milan. Fig. 38 shows the pole-wheel of the same machine; Fig. 39 parts of the 15 generators, each of 5000 kVA, 115 r.p.m., 6300 V, 50 cycles, also mentioned in last year's report as having been built for an outdoor power station [1].

We got an order, in the spring of 1936, for the complete electrical equipment of the big hydro-electric power station of *Barbablanca* in Peru belonging to

[1] In our last report, these generators were said to be for the first generators for an outdoor power station built in Europe. This was an error and we desire to state, here, that two older stations of this type, by two different firms, have already been built in Europe.

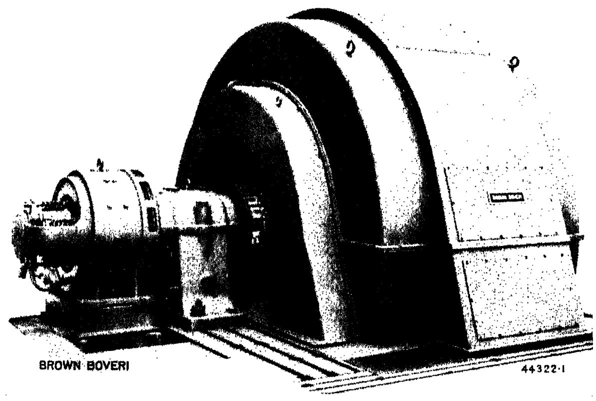


Fig. 40. — Barbablanca, Peru, Empresas Eléctricas Asociadas, Lima. Three-phase generator 17,500 kVA, 6000—6500 V, p. f. = 0·7, 514 r. p. m., 60 cycles.

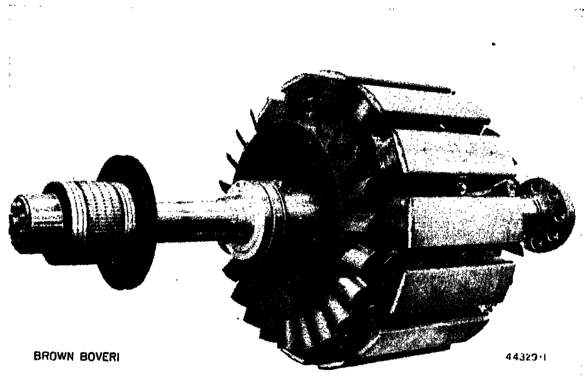


Fig. 42. — Barbablanca, Peru, Empresas Eléctricas Asociadas, Lima. Pole wheel of three-phase generator 17,500 kVA, 6000—6500 V p. f. = 0·7, 514 r. p. m., 60 cycles.

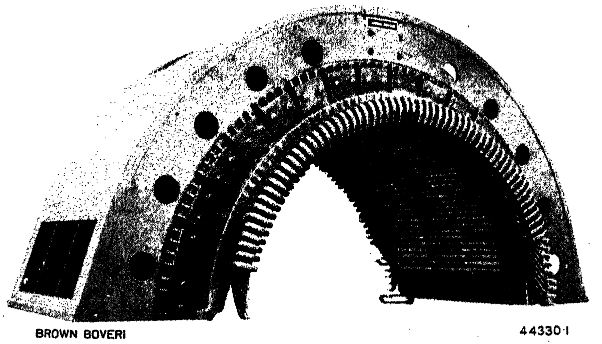


Fig. 41. — Barbablanca, Peru, Empresas Eléctricas Asociadas, Lima. Stator half of three-phase generator 17,500 kVA, 6000—6500 V, p. f. = 0·7, 514 r. p. m., 60 cycles.

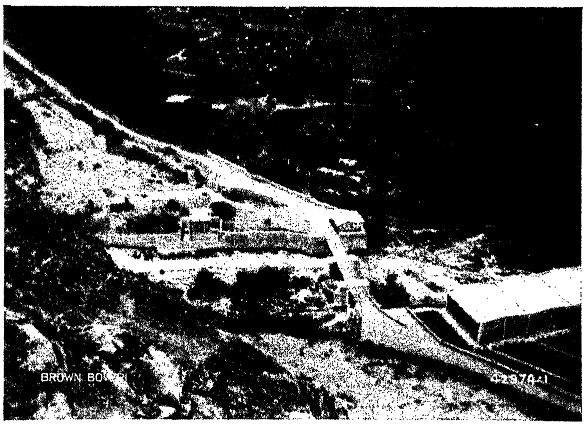


Fig. 43. — Building site of the power station for Barbablanca, Peru. Empresas Eléctricas Asociadas, Lima.

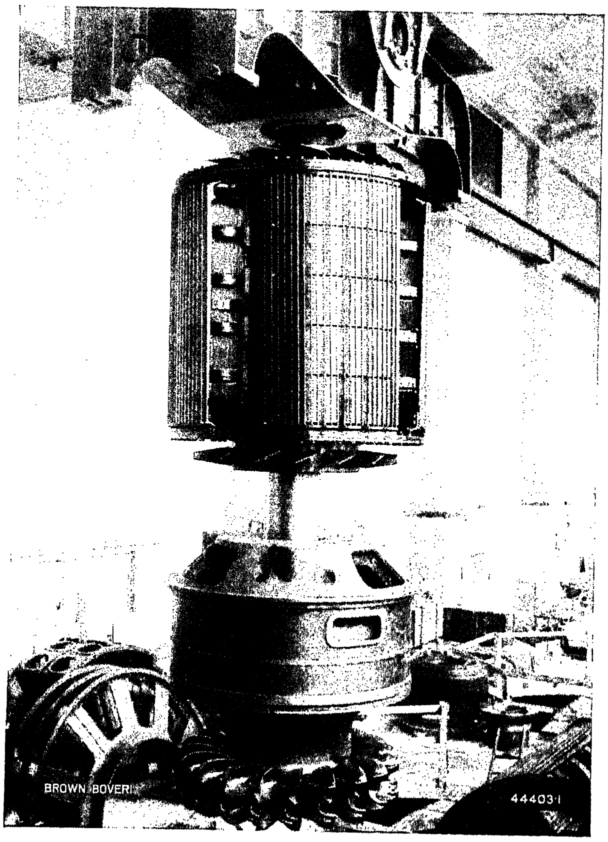


Fig. 44. — Etzel Electricity Works. Altendorf Power Station.
Rotor with crane girder for the single-phase generator 18,000 kVA, 11 kV, 500 r. p. m., $16^2/_3$ cycles with lower guide bearing and flanged-on turbine runner. Erection weight with crane girder about 100 t.

the *Empresas Eléctricas Asociadas* in Lima. This station is 54 km from Lima and will be equipped with two generating sets, in its first development stage, a number which will subsequently be increased to three. The generators are of horizontal-shaft type for direct coupling to 17,150 H. P. Pelton-wheel turbines, each is of 17,500 kVA continuous rated load, 6500 V, 514 r.p.m., 60 cycles. Fig. 40 shows a complete generator on our test bed, before freighting. Figs. 41 and 42 show the half of a stator and a pole-wheel, respectively. Fig. 43 shows the site of the power station. The switchgear plant of the station is mentioned elsewhere.

Fig. 44 is a view of the erection of the single-phase generators in the Altendorf Power Station of the Etzelwerk Co. (Switzerland).

Finally, we would record the order of four three-phase generators, each of 15,600 kVA, 214 r.p.m., 6300 V, 50 cycles which was placed, at the end of 1936, for the Roznow Power Station in Poland. These units will be built by Brown, Boveri & Cie. A.-G., Mannheim-Käfertal.

2. *Big transformers.*

These have continued to be built to designs already laid down and which have given such excellent results in practice. A great number have been built with tap switches the latest designs of which, as described in our last report, have given great satisfaction. Both we and our concessionaries have had a large number of transformers to deliver, of which the great majority was for natural cooling of the oil filling.

Mention should be made of two three-phase regulating transformers, each of 12,000 kVA, 25,000 + 20 × 180 V/7150—7000 V for the Superusina de Puerto Nuevo of the Cia. Italo-Argentina de Electricidad, in Buenos Aires, two three-phase regulating transformers, each of 12,000 kVA, 6300/171,000 150,600 V for the Zjednoczenie Elektrowni Okregu Radomsko-Kieleckiego (ZEORK), further, for the same plant, two three-phase three-winding transformers for 11,000/11,000/6666 kVA and 164/38·7/7·25 kV, all windings having taps which can be operated, the transformer being dead, by means of tap-changing switches. Further, we would mention a three-phase regulating transformer for 15,000 kVA, 6000 + 23 × 73 V/7170 V for the Laufenburg Power Station (Switzerland) and a 15,000 kVA unit, 6760/50,600 V for the same station and, finally, two three-phase transformers each 17,150 kVA, 6500/64,740 V for the Barbablanca Power Station, Peru, already mentioned (Fig. 45). The latter station operates in parallel with Santa Rosa Substation which will contain three single-phase transformers for 3 × 1563 kVA, 32,500/29,250 V/10,000 V, connected delta/delta and also built by us.

A three-phase regulating transformer was delivered to the Faal Power Station in Jugoslavia; it is of 1600, 3200, 4800 kVA primary, secondary

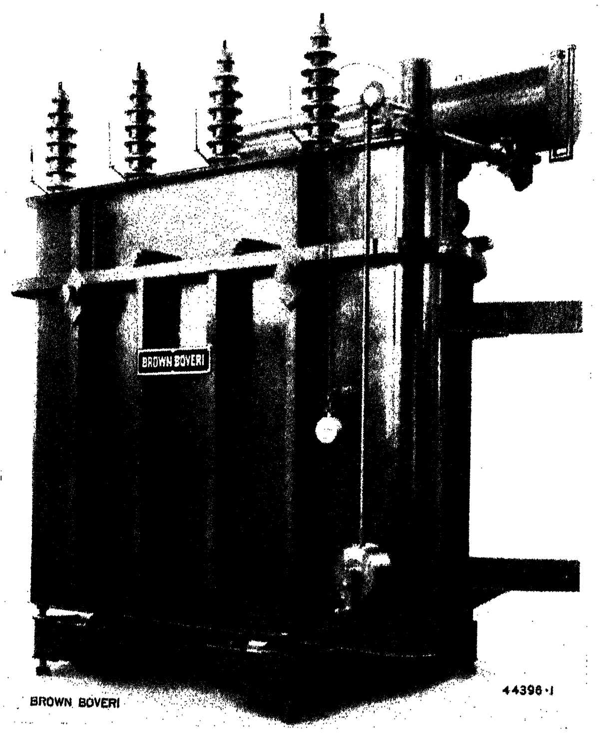


Fig. 45. — Three-phase oil-immersed transformer 17,150 kVA, 6500/64,740 V, 60 cycles, belonging to Barbablanca Power Station, Peru, Empreas Eléctricas Asociadas, Lima.

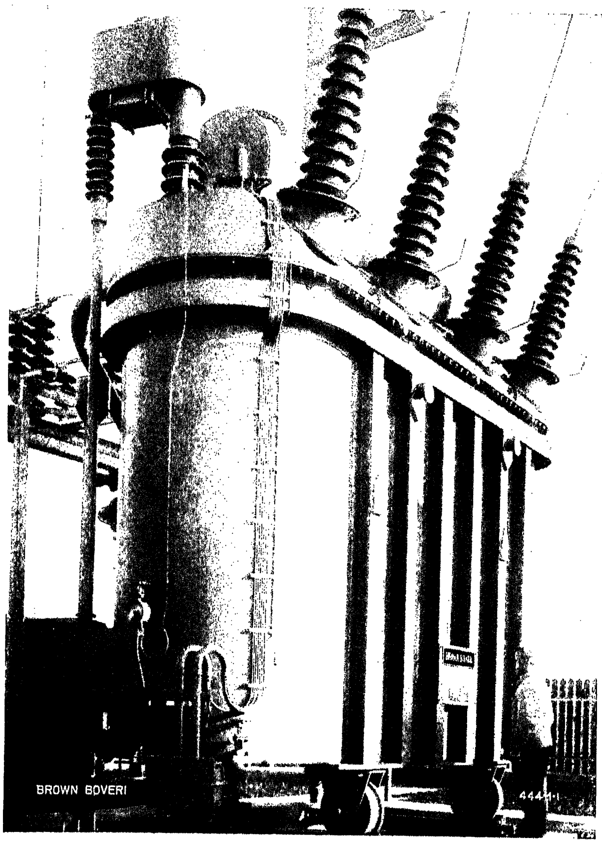


Fig. 46. — Three-phase outdoor regulating transformer, 32,500 kVA, 167,000/48,490 + (23 × 822) V for the outdoor station of the Olten-Gösgen Power Station of the Aare-Tessin Co., Olten.

and tertiary output and designed for a voltage ratio of 11,200/27,500/37,500 V + 15 %. Secondary and tertiary windings are in auto-connection together. With this design it was possible to eliminate a two-winding transformer of 1600 kVA and a regulating transformer of 4800 kVA, as both units are now combined in one. This means lower first cost, lower installation costs and smaller losses.

The 32,500-kVA transformer for the outdoor station of the Olten-Goesgen plant (Switzerland) is shown, on site, in Fig. 46.

At the end of 1936, the Bernische Kraftwerke (Switzerland) ordered a three-phase transformer for their Mühleberg Power Station. This transformer is to be built to be regulated under load in such a manner that the 20,000-kVA output can be delivered at all voltages within the following limits, namely: — high voltage 137—143 kV; low voltage, service I, 15·66—17·5 kV, or, service II, 31·3—35 kV, or, service III, 47—52·5 kV. The low-voltage winding can be switched over to any one of the three services, the transformer being dead, by means of a built-in change-over switch, while, on the high-voltage side, the voltage is set by on-load tap switches.

One of our concessionary companies got an order for two 30,000-kVA transformers, for 4 × 5·85 kV low voltage, the high voltage of which can be regulated, by means of a tap switch inserted at the star point, by ± 20 % in ± 12 taps. These units are so designed that they can be freighted complete, with their terminals and tap switches, on a low-swung railway truck.

3. *Circuit breakers.*

The air-blast high-speed circuit breaker has been gaining ground, during the past year. It would appear to be the breaker of the future, as far as can be seen to-day, this, at least, up to that range of voltage at which the oil-circuit breaker of small oil capacity (convector circuit breaker) becomes the most suitable type.

For this reason, the series of our standard *air-blast high-speed circuit-breakers* has been extended, systematically. We had the opportunity of building a large number of these breakers to our type 64 kV (Fig. 47) which had already been designed at the end of 1935. Among these there are 13 units for the Barbablanca plant, already mentioned and for its Santa Rosa substation, five units for the Town of Zürich Electricity Works (Switzerland). The series of air-blast high-speed circuit breakers for 11 kV was increased by a bigger type for 650 MVA rupturing capacity (Fig. 48) up till then, the types built were for 100, 250 and 400 MVA. The same series for 11 kV rated voltage was completed by breakers for currents over 1000 A, namely for 1600, 2500 and 4000 A (Figs. 49 and 50).

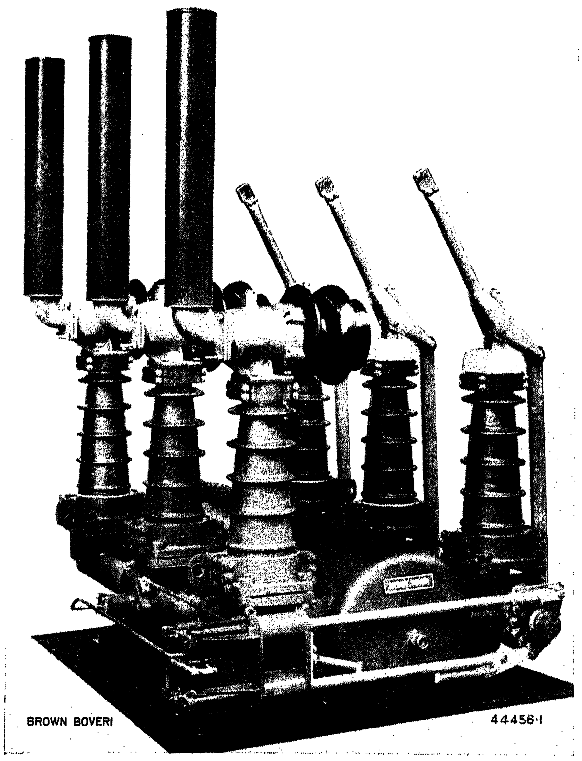


Fig. 47. — Air-blast high-speed circuit breaker of 64 kV rated voltage, 640 A rated current, 800 MVA rated rupturing capacity.

In order to gain information as to the readiness for service of the air-blast high-speed circuit breakers, we carried out a series of interesting duration tests in our shops to determine the behaviour of the breakers, in the open air and under different conditions of temperature. These tests extended over a considerable length of time, and were, partly, without and partly with switching operations at determined intervals. The results proved the great reliability of the valves fitted on the said breakers.

For high and for the highest voltages, our *convector circuit breaker* has given further proofs of its qualities in practice. Among other breakers of this type built, mention may be made of a three-pole set delivered to the Goesgen Power Station of the Aare-Tessin Co. (Switzerland), which is for 150 kV rated voltage (Fig. 51), while, for the Altendorf Power Station of the Etzel Electricity Works Co. (Switzerland), four similar sets were ordered each for 1950 MVA rupturing capacity.

Fig. 52 shows one "pole" of a convector circuit breaker built for 220 kV rated voltage and 2000 MVA rupturing capacity. The total oil filling of a three-pole set, for 220 kV is only about 850 litres as compared to about 65,000 litres which would be necessary for a triple-tank oil circuit breaker of the earlier design.

We described our new *power-storage drive* for a torque of 7·5 mkg in our last

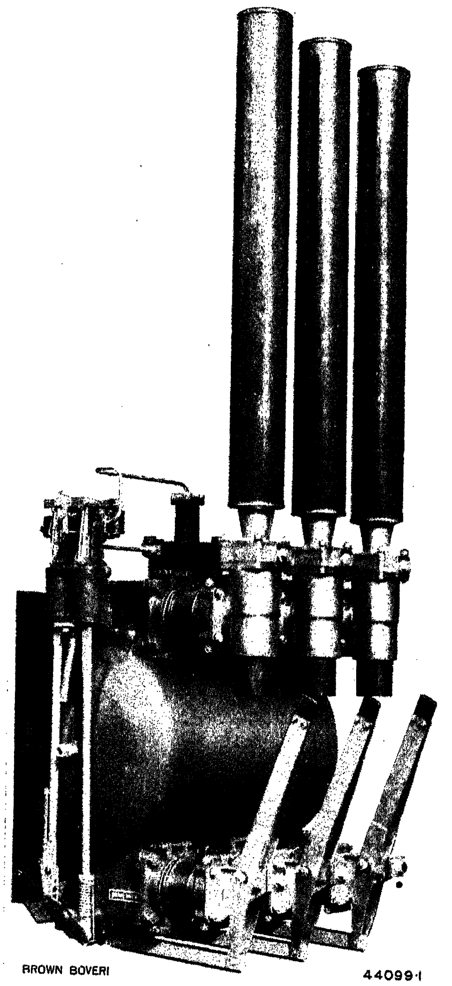


Fig. 48. — High-capacity air-blast high-speed circuit breaker.
11 kV rated voltage, 1000 A rated current, 650 MVA rated rupturing capacity.

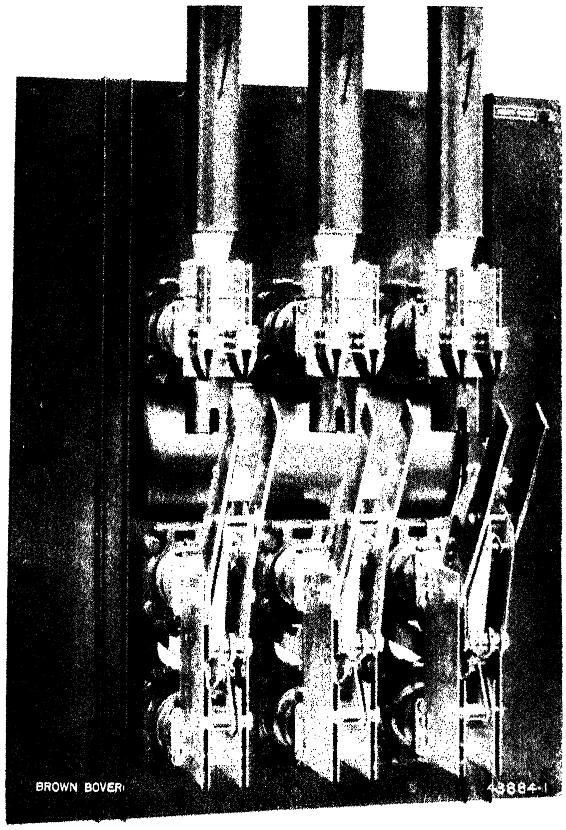


Fig. 49. — Air-blast high-speed circuit breaker.
11 kV rated voltage, 2500 A rated current, 400 MVA rated rupturing capacity.

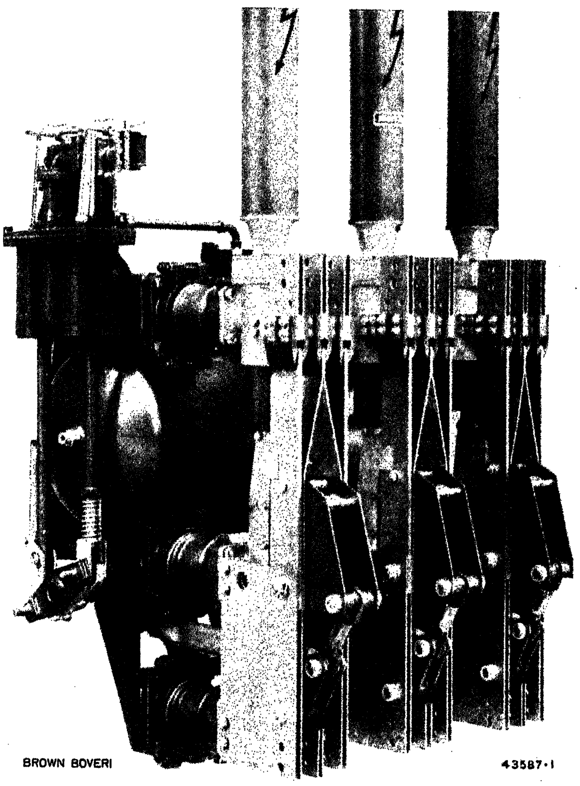


Fig. 50. — Air-blast high-speed circuit breaker.
11 kV rated voltage, 4000 A rated current, 400 MVA rated rupturing capacity.

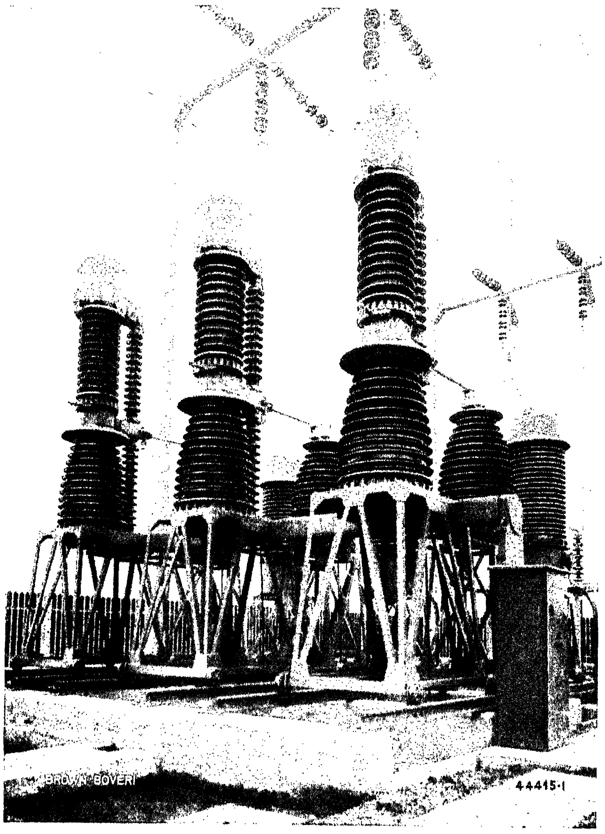


Fig. 51. — Convector circuit-breaker set of the outdoor station belonging to the Olten-Gösgen Power Station of the Aare-Tessin Co., Olten. With separate current and voltage transformers, for connecting the power station to the big Gotthard transmission line.

year's report. This drive can be combined in most happy manner with a reclosing device which had, always, to be installed separately up till now as it comprised, at least, two pieces of apparatus. Now that it has been combined in a single one it can be built on to the power-storage drive (Fig. 53).

Our *disconnecting switches* and *change-over disconnecting switches* for voltages up to 37 kV have been entirely redesigned. They are characterized by the ease with which they can be installed and by clamped insulators in the place of cemented ones. The compressed-air drive used is their most interesting feature. Fig. 54 shows one of the new type of switches for 11 kV rated voltage and 400 A rated current, actuated by a compressed-air drive with governing valve.

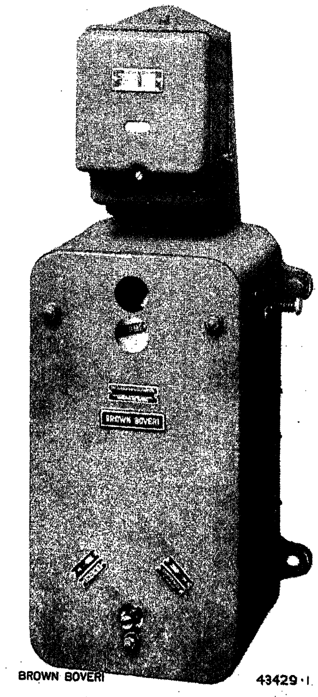


Fig. 53. — Power-storage drive with built-on reclosing device.

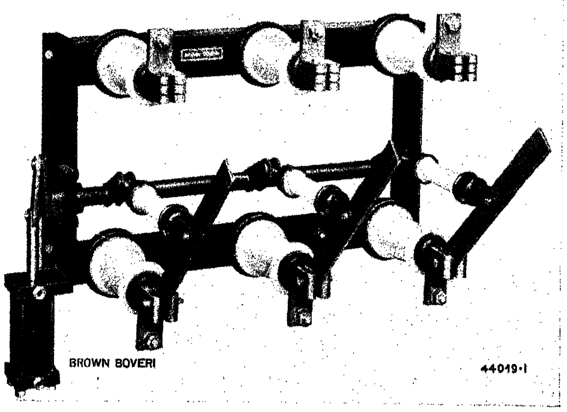


Fig. 54. — Three-pole disconnecting switch with compressed-air drive. 11 kV rated voltage, 400 A rated current.

The need to be able to switch disconnecting switches while under load, under certain circumstances, has been becoming increasingly evident of late. We have met this requirement for *on-load disconnecting switches* by a new design according to Fig. 55. It is intended to bring out a series of these switches for the range of 6·4 to 37 kV, 400 to 640 A and

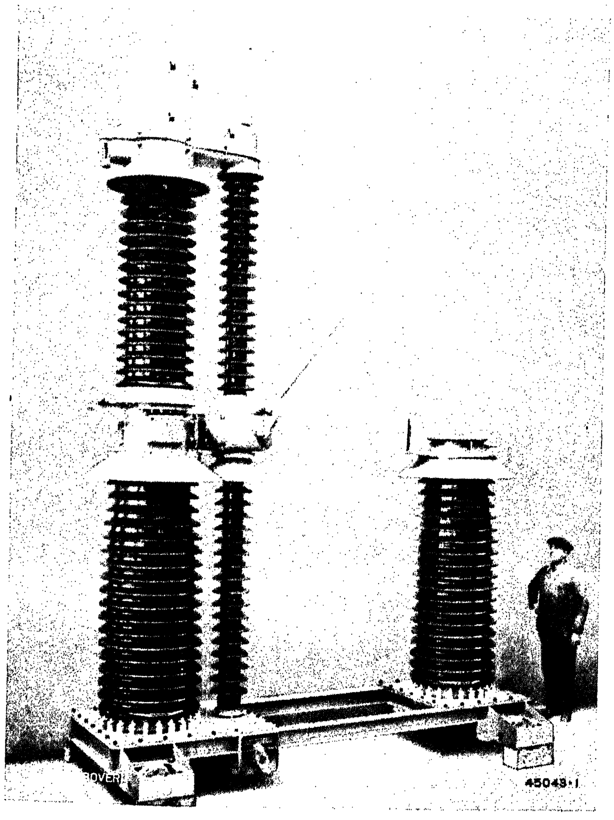


Fig. 52. — "Pole" of a convector circuit breaker for 220 kV rated voltage and 2000 MVA rated rupturing capacity.

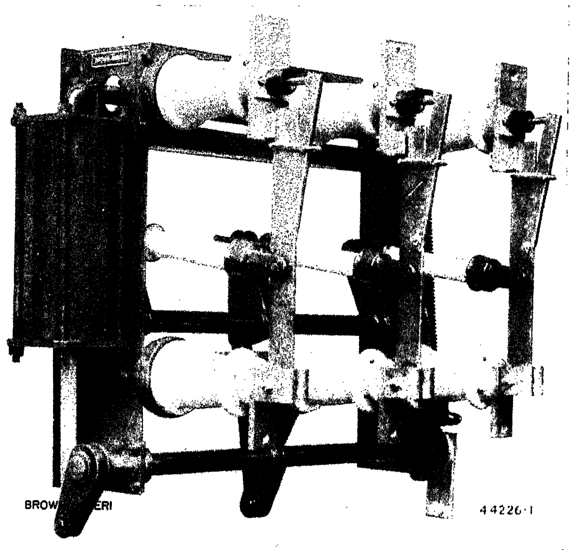


Fig. 55. — On-load disconnecting switch.
11 kV rated voltage, 400 A rated current, 10 MVA rated rupturing capacity.

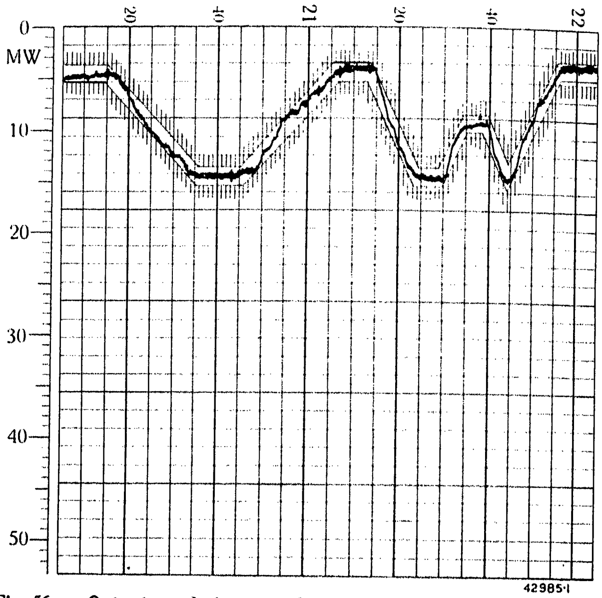


Fig. 56. — Output-regulating record chart, according to programme, in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

5 MVA rupturing capacity. Being convinced partisans of compressed air as an extinguishing medium, we have designed the new on-load disconnecting switches as compressed-air switches. Extinction of the arc takes place in the head of the upper insulator. The compressed air is generated by the switch, itself, by its own action. In some cases the switches are combined with our high-voltage fuses which are reported on elsewhere in this number.

4. *System regulation.*

It is becoming more and more important to big power stations to be able to regulate automatically the output of the station in accordance with a programme or load chart fixed in advance and in conjunction with the maintenance of the frequency. We have devoted careful study to this problem of the automatic regulation of the frequency and the output on big distribution systems.

An order received from the "Energie Electrique du Haut-Rhin" for the delivery of a complete frequency and output regulating equipment for Kembs Power Station gave us a welcome opportunity of investigating the manifold requirements of a big distributing system. The equipment delivered is based on the latest knowledge acquired and shows a high degree of adaptability chiefly as regards working with hydraulic or steam turbines. The results attained have given entire satisfaction.

Fig. 56 shows in diagrammatic form with what a remarkable degree of exactitude an output programme laid down in advance can be held to, in practice, with the help of our frequency regulator and output-programme regulator. The curve really attained or "actual curve" is seen to be between the two straight lines representing the limits of the desired or "specified line". Figs. 57 and 58 shows other output and frequency curves with hand regulation of these values and Figs. 59 and 60 the same for automatic regulation.

Apart from the frequency regulation in the Kembs station, carried out for the first time, we would say that our frequency regulator and output-programme regulator allow of solving a whole series

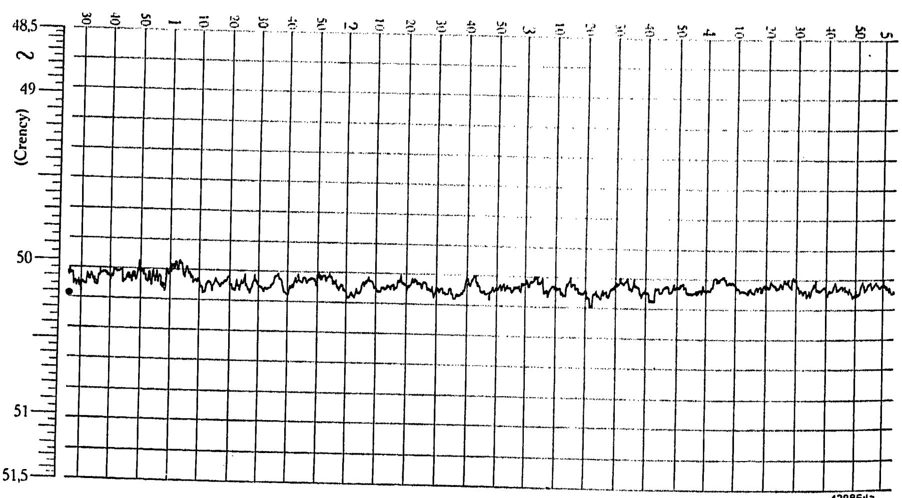


Fig. 58. — Frequency curve with hand regulation, in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

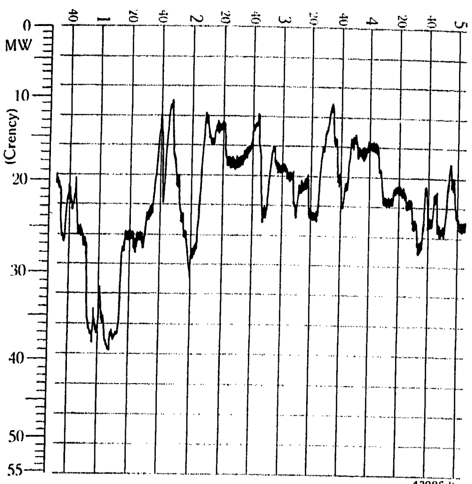


Fig. 57. — Output-curve with hand regulation in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

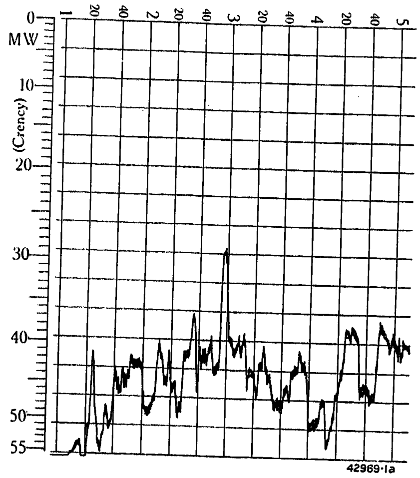


Fig. 59. — Output curve with automatic regulation in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

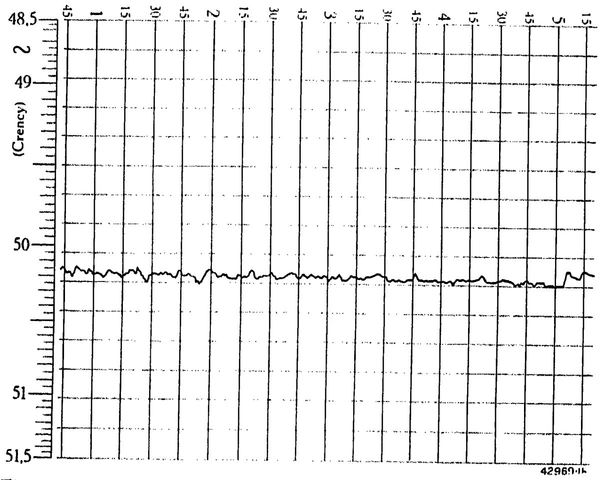


Fig. 60. — Frequency curve with automatic regulation in the Kembs Power Station of the "Energie Electrique du Haut-Rhin".

of regulating problems. Thus, it may happen on systems which are not in parallel with other systems and, themselves, supplied from hydraulic plants without sufficient storage accommodation, that the superfluous power available at given periods should be taken over by some big power consumer (electric furnaces for example); or else it happens that a large number of small plants having their own power supply also work in parallel with a big system, the duty of which is to cover their peak-load requirements; or, yet again, D. C. motors have to be regulated which are used to drive three-phase generators or industrial machinery. All such problems can be solved, simply and precisely, by our apparatus which can be added to any power station and has the advantage of improving the operating qualities of old turbine governing equipments so as to make them more capable of meeting modern requirements.

5. *Relays.*

In our last year's report, we gave some information on our new *current-indicating secondary relay Type S,* which has had a most encouraging reception, in practice, thanks to its excellent service properties. Figs. 61, 62 and 63 show different ways of installing the relay which have been developed, in the mean time, namely for mounting and connecting on the front of the switchboard panel, for countersunk installation and for mounting on the panel but with connections from the rear. Fig. 64 shows a further development of this relay in the form of a voltage relay.

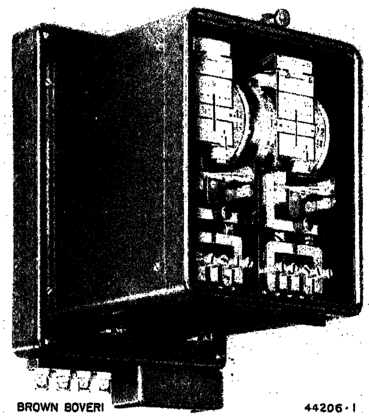


Fig. 61. — Secondary relay, in case, for connection in front (mounting in front of panel).

Further, we have developed an *auxiliary* relay for D. C. and A. C. (Fig. 65) for 380 V rated voltage and 6·3 A which can be used as a signal relay or as a contact relay. In the former case, it is equipped with a signal drop disc and, in the latter, with two closing and two change-over contacts, or a device for contact retardation and two closing contacts.

Finally, in this connection, mention should be made of a new kind of signalling apparatus (Fig. 66).

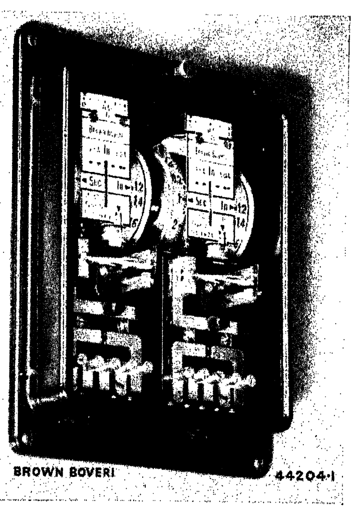


Fig. 62. — Secondary relay, in case, for counter-sunk mounting.

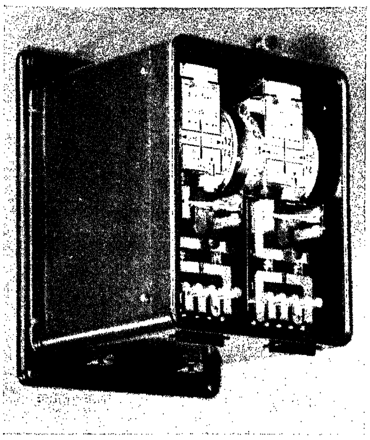
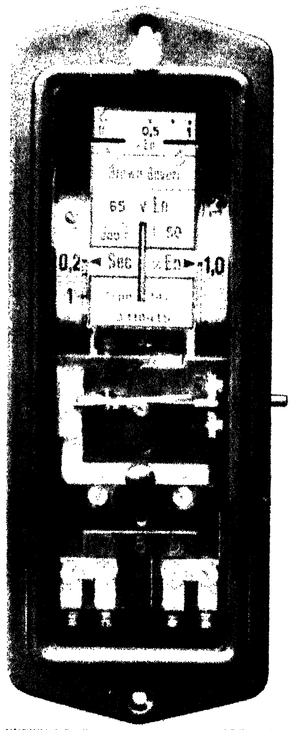


Fig. 63. — Secondary relay, in case, ready to be mounted.

In order to allow of testing different designs of relays, which may be built for very different current strengths, both quickly and with a minimum of trouble, we have developed a portable *relay-testing apparatus* (Fig. 67) for primary-system connection and composed, in essential, of a transformer without oil filling in a sheet-metal housing. The secondary winding thereof has taps to be connected to the relays being tested. The taps correspond to the big steps 5—21 A, 22 to 75 A, 76—225 A, 226—670 A, 671 to 2000 A, while the close setting of the testing-current strength, between the big-step limits, is effected by the displacement of a magnetic leg or column on the transformer by means of a handwheel, after the method used in our welding transformers.

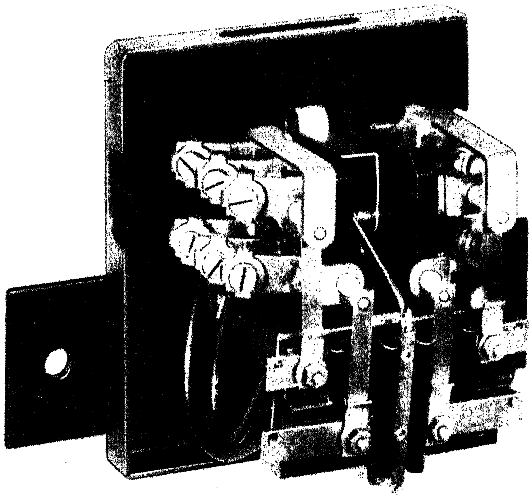
6. *Switchgear plants.*

The new *air-blast high-speed circuit breaker designs* allowed of introducing some new features to medium-voltage switchgear plants. Mention should be made of the 13-kV switchgear plant delivered



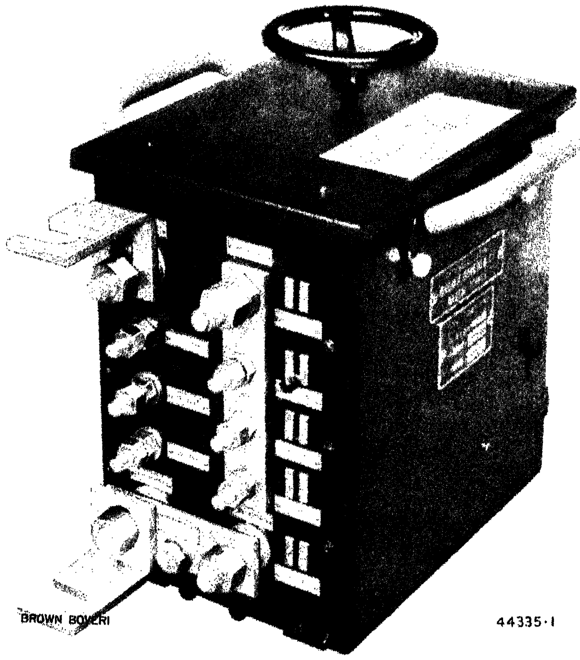
BROWN BOVERI 43746-I

Fig. 64. — Maximum voltage relay.



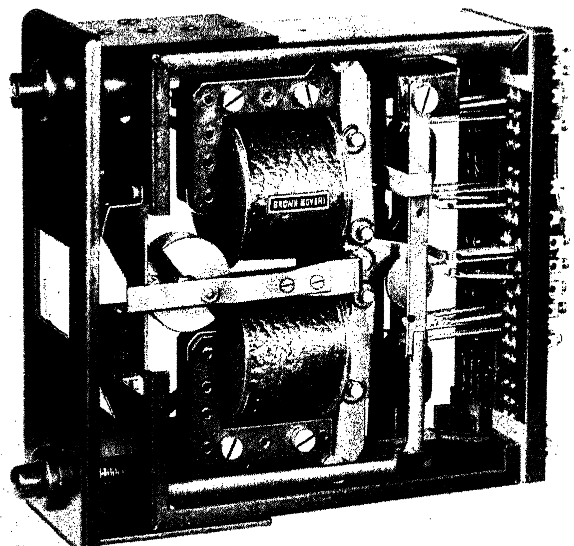
BROWN BOVERI 44431-I

Fig. 65. — Auxiliary relay for D.C. and A.C. for 380 V rated voltage.



BROWN BOVERI 44335-I

Fig. 67. — Relay-testing apparatus.



BROWN BOVERI 44177-I

Fig. 66. — Signalling apparatus.

to the Cie Vaudoise des Forces Motrices des Lacs de Joux et de l'Orbe in Cossonay (Switzerland) which is shown in Figs. 68 and 69. These illustrations show up, clearly, the sharp separation of the compressed-air mechanism and low-voltage equipment from the high-voltage parts of the breaker. This makes it possible to supervise the low-voltage and compressed-air parts such as auxiliary contacts for signals, control-electro-magnets, compressed-air cylinder, valves etc., and even to do work on these parts, while the breakers are under voltage or in service.

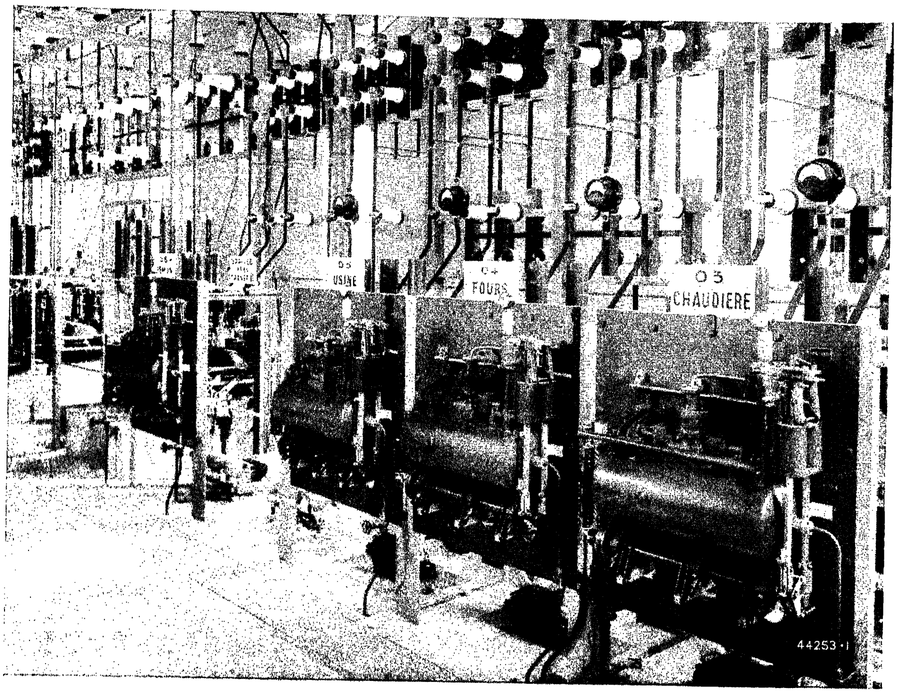


Fig. 68. — 13-kV switchgear plant with air-blast high-speed circuit breakers, belonging to the Cie Vaudoise des Forces Motrices des Lacs de Joux et de l'Orbe, Lausanne; Cossonay Station.
Low-voltage side.

It is possible to achieve simple, compact and safe switchboard layouts, with the help of air-blast high-speed circuit breakers, which it is not possible to attain when other types of circuit breakers are used.

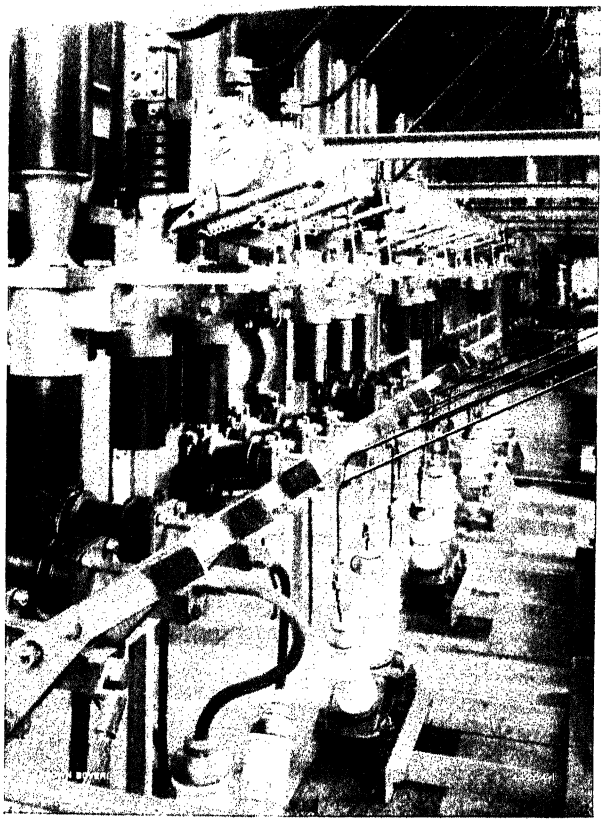


Fig. 69. — 13-kV switchgear plant with air-blast high-speed circuit breakers, belonging to the Cie Vaudoise des Forces Motrices des Lacs de Joux et de l'Orbe, Lausanne; Cossonay Station.
High-voltage side.

The compressed-air generating and distributing plants belonging to these breakers have given full proof of their reliability and are not to be considered as troublesome auxiliaries to the switchgear plant, at all; all operators agree that their availability allows of solving, elegantly, a whole series of other secondary problems. By using suitable designs, the loss of air pressure has been so much reduced that the compressed-air generator only has to run once or twice a week, if no switching of the breakers takes place, in the meantime.

The arrangement of control and recording apparatus and, as necessary, of instruments and other apparatus in the diagrams of connection of mimic switchboards is much appreciated by the personel of

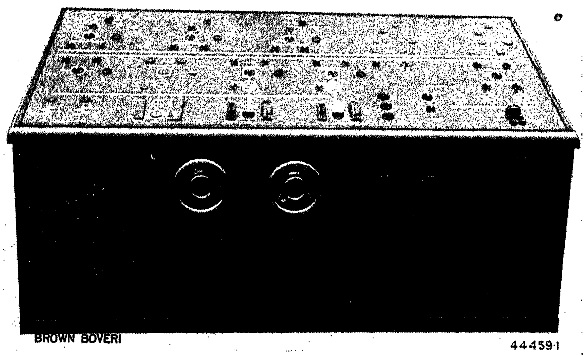


Fig. 70. - Control desk board of the Barbablanca Power Station, Peru.

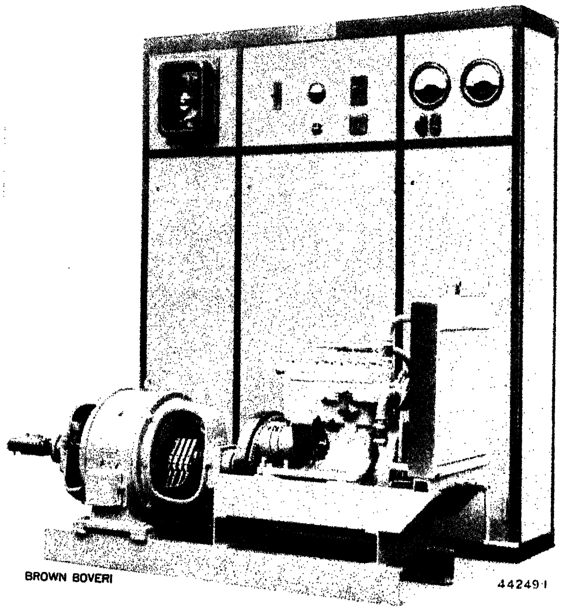


Fig. 71. — Petrol-electric emergency set. Three-phase 15 kVA, 380/220 V, 50 cycles.

stations. A desk board of this type is shown in Fig. 70, it is that of the Barbablanca Power Station, Peru. This plant, as said before, has two generators of 17,500 kVA, 6 kV and two transformers of 17,150 kVA, 6/64 kV, as first development stage and, along with the making over of the Santa Rosa Substation belonging to it, for the supply of the capital city of Lima, forms one of the most interesting orders booked in 1936. According to modern principles, both stations will be fitted with air-blast high-speed circuit breakers. Brown Boveri delivered the complete electrical equipment of the said stations.

Emergency sets have often been used, recently, to assure power supply to services which must be kept up at all costs. In collaboration with engine builders, we have developed completely-automatic sets for this purpose, with which the time elapsing between the failure of the usual source of power and the beginning of power supply from the emergency set is reduced to few seconds.

Fig. 71 shows a type of wall switchboard which swings out to allow of making both front and back accessible.

The *starting (ignition and excitation) set* for mutator plants has been newly designed. Fig. 73 shows, very clearly, how it is possible to design a pleasing apparatus taking up little room, by well thought-out combination of transformers, relays, resistances and terminals.

In the field of *high-voltage testing plants*, new and interesting designs have been brought out. The Sté d'Exploitation des Câbles électriques in Cortaillod (Switzerland) ordered a complete high-voltage testing plant from us, to generate 800 kV (r. m. s. value) and a D. C. voltage of 1000 kV. Special mention should be made, here, of the needle-type rectifier combined with the testing transformer (Fig. 79).

The following new designs of apparatus, which belong to switchgear plants proper, are worthy of note.

We have replaced the former design of *high-capacity fuse* by a new one as we found that the types used up till now did not fulfil all modern requirements. As will be recalled, extinction of the arc, in the former type of fuse, was effected by the sudden generation of gas when

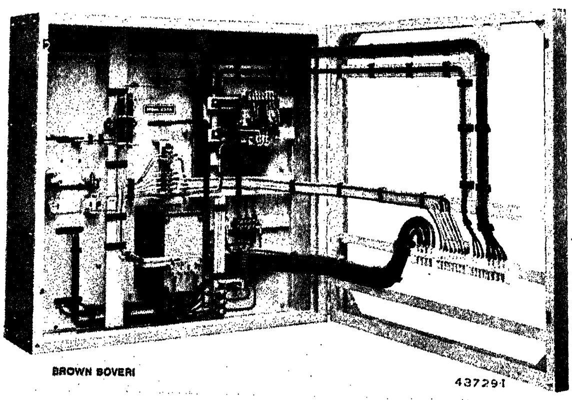


Fig. 72. — Wall-switchboard for pumping station.
Back view, board swung out.

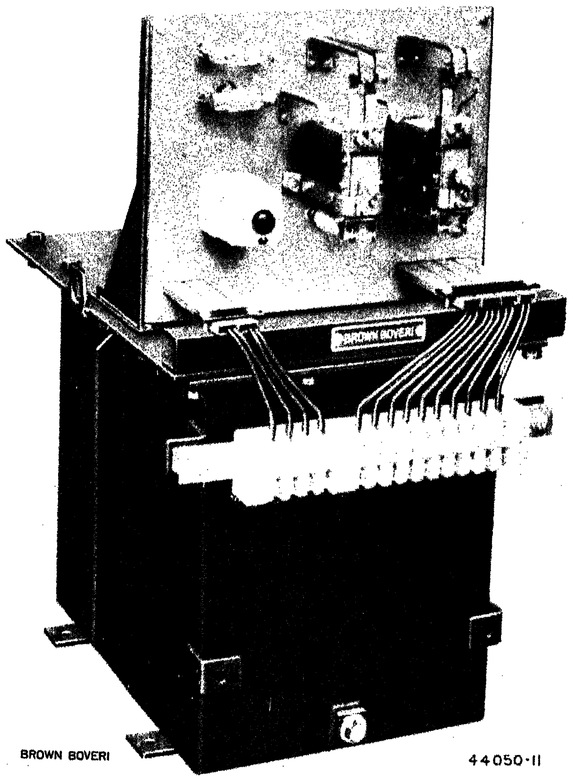


Fig. 73. — Ignition and excitation set for mutators with ignition by dipping. Front view.

the fuse wire proper melted, which produced a powerful extinguishing blast passing from the inside of the tube towards both ends. This self-producing extinction limited the rupturing capacity of fuses, in many cases, notably when the ruptured current was weak, on account of the correspondingly small amount of power in the arc. Under unfavourable conditions on the system, continuous arcs were set up in this way. In the case of heavy currents ruptured, on the contrary, the pressures generated were apt to be excessive and often caused the fuse-tubes to burst. Only average-strength currents could be ruptured with relative certainty and, in any case, when putting in these fuses the possibility of the metallic vapour ejected causing flash overs in the switchgear had to be kept in mind.

It is also possible to use liquids to extinguish the arc. Oil fuses rupturing very high currents are the seat of extremely high pressures and can explode and cause fires. In the well-known type of fuse working with tetra-chloride filling the danger of fire is eliminated but not that of the fuse bursting, further, the operation of the fuses causes the generation of poisonous gases and these attack the surrounding gear chemically.

Our investigations have led us to develop a fuse principle which eliminates the defects just enumerated. Investigations in our high-power testing plant proved to us that careful dimensioning and design of the fuse wire is essential to reliable operation of the fuse and that great importance attaches to using, for fuse wire and filling, materials which are chemically suitable to one another. The fuse wire in the tube is embedded in a special filling material. The gases generated, when the wire fuses, diffuse in the said filling and the arc is ruptured owing to the great amount of heat subtracted from it. Extinction is so intensive and so rapid that a short-circuit current cannot develop completely at all but is limited and cut out in its

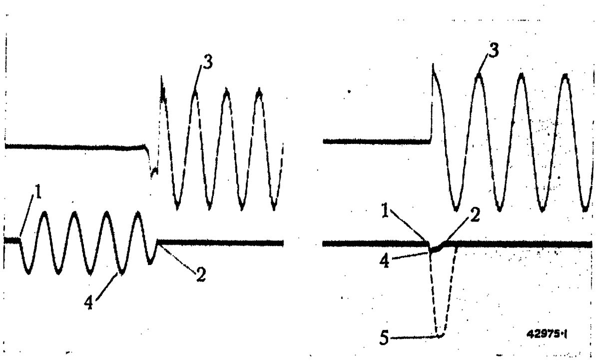


Fig. 74. — Rupturing oscillogram produced with 11 kV, 10 A, high-capacity fuse.

Left
1. Beginning of overload.
2. End of rupture.
3. Recovery voltage.
4. Current load 95 A.

Right
1. Beginning of short circuit.
2. End of rupture.
3. Recovery voltage.
4. Highest current peak attained 150 A.
5. Short-circuit current set for 15,200 A.

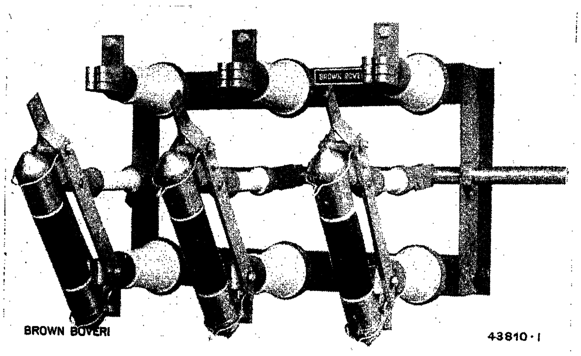


Fig. 75. — Three-pole high-capacity isolating fuse, 11-kV rated voltage.

initiation period (Fig. 74). Thus, both fuses and plant are protected from electro-dynamical repercussions. When a fuse of this type melts, there is no inner pressure rise or outside phenomena such as flames, vapour production, detonation. The current does not fall suddenly after the rupture but goes back to zero after a certain, if very short, period. The fuse is very reliable in its extinction action, it is independent of the strength of the current and of any blow-out effect. No continuous-arc formation is possible. The fuse-tubes of the new design are of ceramic material which cannot be affected either by an overload or by the extinction process and does not carbonize like paper or paper preparations. Thus, high fuse-wire temperatures can be allowed which means short fusing time and, therefore, closer selectivity. Our new fuses have no cemented parts, can, thus, be used in the tropics and are also unaffected by salt or acid in the surrounding air. Fig. 75 shows one of the new high-capacity fuses.

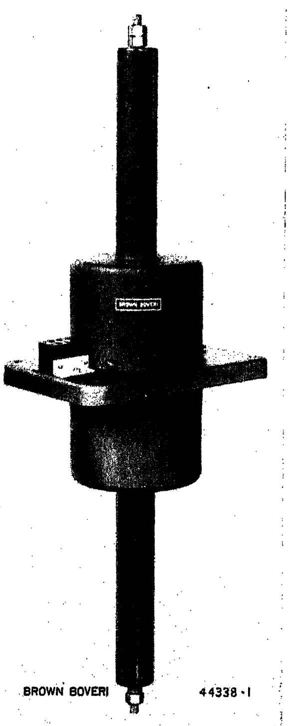


Fig. 76. — Bushing-type current transformer, 37 kV rated voltage, 250 A rated current.

The increase in short-circuit outputs to be dealt with, which is encountered everywhere, gives enhanced significance to the design of very high short-circuit current proof current and voltage transformers. This is especially the case for *bushing-type current transformers.* These are absolutely short-circuit proof if they are properly designed; it is easier to dimension them so that they are satisfactory from the

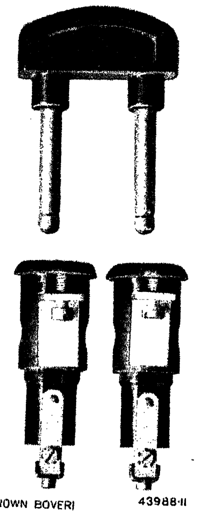


Fig. 77. — Plug contact.

thermal point of view. This makes them superior to all other current-transformer types to such a point that it must be considered a fault to put in anything else than bushing-type transformers if a suitable design thereof is really available and can be lodged in the space available.

This fact and the recognition that bushing-type transformers of the kind in use up till now, for the current ranges of 100 to 200 A and below, were much too expensive, caused us to remodel existing designs. We have been successful in bringing out a new series (Fig. 76) in which the amount of material used is brought down to a minimum without affecting quality, in any respect. The field of utilization includes voltages of 1·5 to 110 kV and primary-current strengths of 5 to 2500 A. This range of transformers is characterized by its great adaptability to all possible conditions of service.

By making efficient use of all the material used in the construction of the new apparatus, a series of *loop-type current transformers* was brought out. These are built for a voltage range of 11 to 110 kV; the range of primary current is limited to 5—250 A. Owing to the considerable length of primary winding which is cradled in the bushings, the loop-type of transformer is, dynamically, very strong against short circuits. As regards heating, it can stand a current 100 times the standard rating for a period of one second.

Mention should also be made of a new design of *plug contact* we have brought out (Fig. 77).

We would like to say here again, that, whenever it has been possible to do so, we have eliminated cemented points in favour of clamped connections in the armatures of the supporting insulators used in switchgear plants and in our apparatus.

An important *outdoor switchgear plant* was built, last year; this was beside the *Olten-Goesgen Power Station* and was put up by the Aare-Tessin Co. (Switzerland). It contains the regulating transformer for 32,500 kVA and convector circuit breakers. Despite its size, the plant, equipped with our material, is characterized by great simplicity and ease of supervision (Fig. 78).

II. POWER DISTRIBUTION AND CONVERSION.

A. TRANSFORMERS.

On-load tap-changing switches are being increasingly used in transformers, particularly in those put into substations. In our last year's report we mentioned our new type of on-load tap-changing switch with coarse and finely-graded selector, and we may say that it has given an excellent account of itself, in practice.

Mention can be made, here, of a three-phase tap transformer for the Breitenbach Substation of the Elektra Birseck in Munchenstein (Switzerland) which unit is of indoor design, with natural cooling, for 4000 kVA and 50,000 V on the high-voltage side. The low-voltage winding is for 12,600 V no-load voltage and can be regulated upwards by an on-load tap-changing switch in 15 steps each of 154 V. A three-phase tap-changing transformer in auto-connection was, also, delivered to the Schüpfheim Sub-

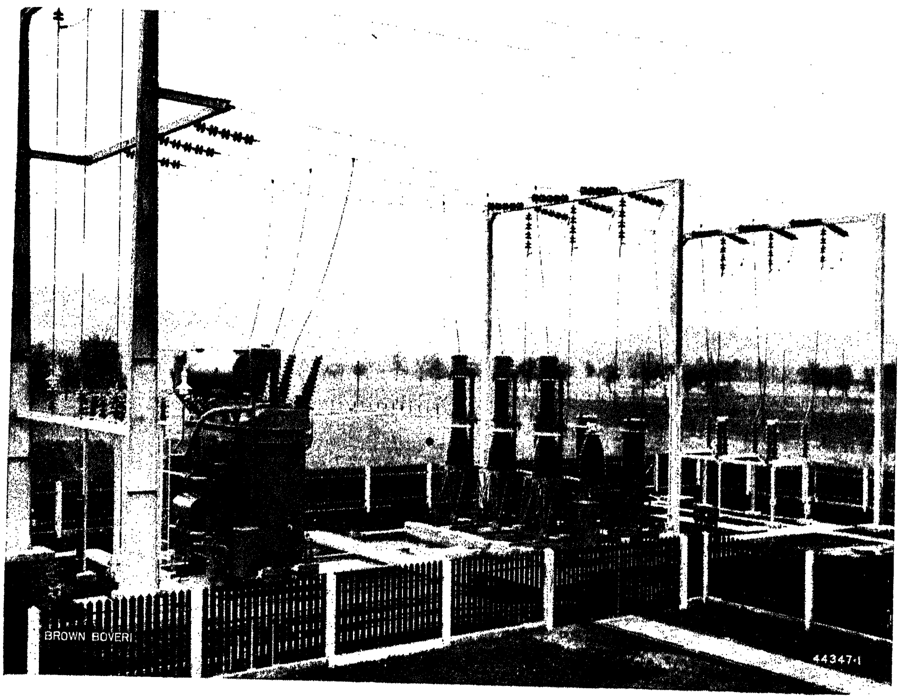


Fig. 78. — Outdoor station of the Olten-Gösgen Power Station of the Aare-Tessin A.-G., Olten, with three-phase regulating transformer for 32,500 kVA, 167,000/48,490 + (23 × 822) V, convector circuit breakers, voltage transformers and disconnecting switches.

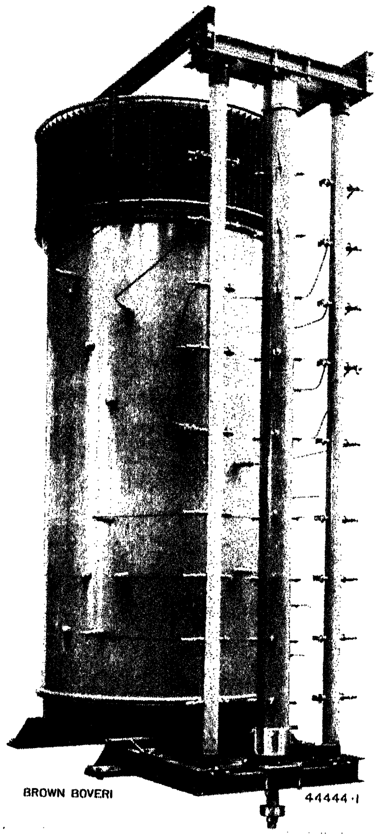


Fig. 79. — **Cortaillod Cable Works. Testing transformer for A. C. 400 kVA. 400 kV (r. m. s.) 50 cycles and for D. C. 500 kV.**

station of the Centralschweizerische Kraftwerke (Switzerland). This unit is, also, for indoor use and is built for 1200 kVA continuous output, 11,250 ± 10×95 V/12,200 V with automatic regulation of the tap-changing switch. Further, we supplied, for the Santa Rosa Substation of the Empresas Eléctricas Asociadas, in Lima (Peru), two three-phase transformers with internal water cooling of the oil filling, each for 17,200 kVA, 51,000 + 23 × 575 V/10,700—10,350—10,000 V, the taps on the high-voltage side being brought to an on-load tap-changing switch while, on the low-voltage side, the taps are connected to a tap switch to be operated when the transformer is cut out.

Mention should also be made of the order received from the Société d'Exploitation des Câbles électriques système Berthoud Borel & Cie in Cortaillod (Switzerland) for two *testing transformers* each of 400 kVA, 1000/400,000 V, 50 cycles to be cascade-connected for 1000/800,000 V, 800 kVA. These units are combined with a mechanical needle-type of rectifier so as to supply an impulse-generating plant at 2000 kV and to allow of D. C. tests at 1000 kV. The formation of the cascade set and the combination with the rectifier along with the leading-out of the taps to be served by the rectifier made it necessary to create a quite new design of testing transformer. Fig. 79 shows the transformer completed, which has already been mentioned in the preceding pages.

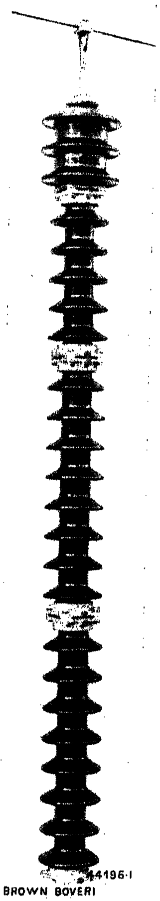


Fig. 81. — Lightning arrestor Type HF 57 and HF 64 respectively 57 kV and 64 kV rated voltage respectively.

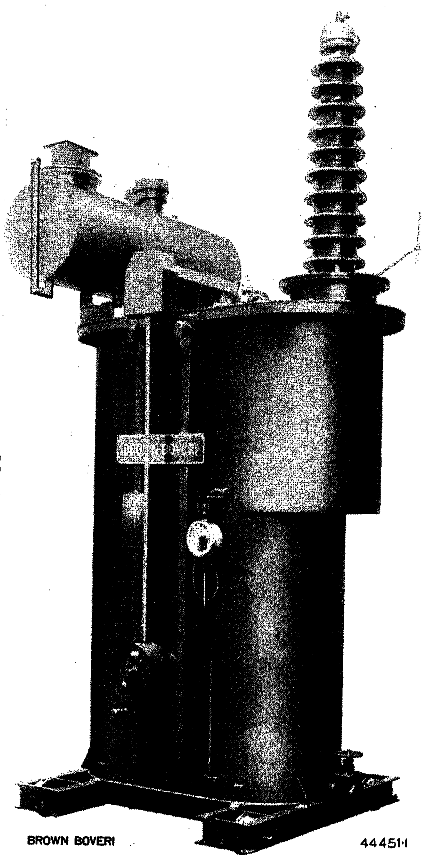


Fig. 80. — Single-phase, oil-immersed dissonance extinguishing coil, 2860 kVA (two-hours rating), 127,000/190 V, 50 cycles, 39—30 A.

B. DISTRIBUTION-SYSTEM PROTECTION.

In last year's report, we mentioned the large number of our *dissonance extinguishing coils* which had been ordered. In 1936, the *Kungl. Vattenfallstyrelsen in Stockholm* ordered from us five of these coils for the Porjus, Lulea, Vannäs, Oernsköldsvik and Bispgarden plants, these being for 7500, 2860, 8900 and 4200 kVA two-hour rating. The unit for the Porjus Power Station, of 8900 kVA, is one of the biggest extinguishing coils ever built. The coil has 15 taps, led to a tap switch in an oil tank and which is of the on-load type. The operator can determine, by means of the on-load tap-changing switch, the symmetry point (resonance point) at any time.

The coil in the Lulea plant is shown in Fig. 80.

The *Resorbit lightning arrestor* of our well-known type has been further developed for voltages between 37 and 64 kV with an absorption capacity corresponding to the increased requirements. Further,

in parallel with the existing series of from 3·7 to 37 kV, we have brought out a new series of arrestors with increased conductive capacity. Fig. 81 shows one of the new 64-kV arrestors, for suspended mounting.

C. THE COUPLING OF SYSTEMS.

The outstanding service results attained with the eleven system-coupling converter sets with commutator cascade connections on the induction side, which, incidentally, led the Swiss Federal Railways, against their first intention, to leave in service the set delivered to the Seebach Substation instead of stopping it, after the starting-up of the new Etzel Power Station, was the reason for the ordering of two further similar converter sets in the course of 1936.

One of the new sets will be placed in the plant of *Spigno-Monferrato of the Acciaierie e Ferriere Lombarde Falck-Milano* (Italy) and will be built by Tecnomasio Italiano Brown Boveri, Milan. It is remarkable both from its layout and the conditions under which it is to work. The vertical-shaft synchronous machine, connected to the three-phase system of the Italian State Railways, is built for 9000 kVA, 500 r. p. m., 3500—4000 V, 16 $^2/_3$ cycles and is coupled, on one side, to a hydraulic turbine and, on the other, to an induction machine to allow, alternatively, of connecting up to the industrial systems, 6300 V, 50 cycles, and 5100 V, 42 cycles. The frequency changer for the separately-placed Scherbius regulating machine is on the same shaft above the induction machine and over the supporting bearing, quite at the top and on the same shaft there is, also, a small auxiliary generator.

Apart from the arbitrary and alternative exchange of power between the two systems, independently of the frequency fluctuations of the said systems, or solely dependent on the frequency oscillations on the railway system, the following kinds of operation are possible:— Connected to the Scherbius regulating motor, the induction machine can run as a pure phase advancer, its reactive output being 5000 kVA at 6300 V, 50 cycles and 4000 kVA at 5300 V, 42 cycles; it can run as an induction generator and as a phase advancer, as well, the commutator machine regulating the reactive load so that the generator delivers between 6500 kW at p. f. = 1 and 7500 kVA at p. f. = 0·86, when connected up to 6300 V and 50 cycles. When connected up to 5300 V and 42 cycles it can give 5400 kW at p. f. = 1 and 6300 kVA at p. f. = 0·86. The active power delivered by the generator is covered by the hydraulic turbine. The induction machine can, however, also work, unconnected to the Scherbius unit, as an uncompensated induction generator giving 6500 or 5400 kW at p. f. = 0·86 to the 50 or 42-cycle industrial systems, respectively. The double-type Scherbius regulating machine is built for 750 r. p. m. and is coupled to a starting three-phase motor with wound armature. The excitation power required for the synchronous machine connected to the railway system is furnished by a special exciter set composed of a three-phase driving motor and a main and auxiliary exciter. A further exciter set composed of a driving motor and three-phase commutator machine, designed as a double unit, delivers the excitation for the Scherbius regulating machine.

Together with a British firm, we got an order for a 25,000-kVA system-coupling converter set, towards the close of last year. This is the most powerful set of its kind built, so far, and is for the *New South Wales Government Railways.*

The duty of the set is the flexible coupling of two three-phase systems of 25 and 50 cycles, respectively. Power exchange is to be in both senses. The induction machine must, also, be able to run as an independent generator. The synchronous machine is connected up to the 50-cycle system and, as a generator, has an output of 25,000 kVA at p. f. = 0·85, over-excited and 11,000 V terminal voltage. The induction machine has the same output and is wound for 6600 V. The frequency on the 50-cycle system fluctuates between 49·5 and 50·5 cycles that on the 25-cycle system between 24·5 and 25·5 cycles. The starting up of the set must be automatic, by push-button control and either from the 50-cycle side or the 25-cycle side. A change-over pole starting motor is used, to this end, which is coupled to the set.

The plant mentioned in our last year's report for the flexible coupling of a 50-cycle industrial system and a 16 $^2/_3$-cycle railway system by means of a single mutator has been completed and tests begun thereon.

D. MUTATORS.

In this field, which is still rich in development possibilities, there are some interesting innovations to record. For the *Soc. pour l'Industrie Chimique, Monthey* (Switzerland) we built a small mutator without water cooling and of the type mentioned in our last year's report. This unit is built for 6000 V and 5 A to supply *an arc-flame furnace* which, it is hoped, will produce more than the single-phase arc furnaces used up till the present. Further, a 300-kW mutator is in course of manufacture for *Soc. Metallurgica Italiana,* the controlled grids of which are to convert 50-cycle three-phase current into single-phase, 1000-cycle current, in order to supply a single phase induction melting furnace.

As a result of further investigations in our laboratories, all mutator types were subjected to certain constructive modifications. Above all, the anode valve was redesigned to meet the latest knowledge available on this subject. The vacuum-pump

set is, now, invariably, built on to the cooling sleeve of the main cylinder. Four supporting feet in the place of three are now delivered and these can be equipped, on request, with insulated rollers (see Figs. 82 and 83).

At the top of the list of mutator equipments ordered last year, comes the order for 27 sets each of 2500 kW output, for 660 V D.C. for the *Southern Railway* which are intended for the various substations on the Portsmouth line, to be electrified shortly. The mutators and their transformers are being built by our concessionaries Bruce Peebles, Edinburgh, the switchgear in the Baden shops. The total number of mutators delivered by us or our concessionaries to the Southern Railway amounts to 68 units, with a total output capacity of 170,000 kW.

Of hardly less importance, is the order for 16 mutator sets each of 1000 kW at 1530 V D.C. for the substations of the Arnhem-Utrecht-Amsterdam-Utrecht-Eindhoven, the Utrecht-Gouda-Rotterdam and the Gouda-Haag lines which the *Dutch State Railways* intend to electrify. This order is all the more worthy of note, because thanks to the excellent results attained with our earlier mutators we were the only European firm to get by far the major part of the order (26 sets) while what remained — 10 sets — went to an American firm. All these new mutators have controlled grids as a protection against back-fires and short circuits. The total number of mutators delivered to the Dutch State Railways amounts to 63 units with a total output capacity of 44,500 kW.

The Pilatus Railway, one of the oldest of our mountain railways has, finally, gone over to electric traction and we were favoured with the order for the substation equipment to supply this line. This comprises two mutator sets each of 600 kW, 1500 V full-load voltage. The primary side is linked up to the 50-kV ring system of the Centralschweizerische Kraftwerke. The two mutator sets are so dimensioned that they can be overloaded by 25% for the duration of the up-grade trip. As is the case of most of the recent railway substations, this one is equipped for fully-automatic operation, the putting in and cutting out of the sets can be carried out from the office for

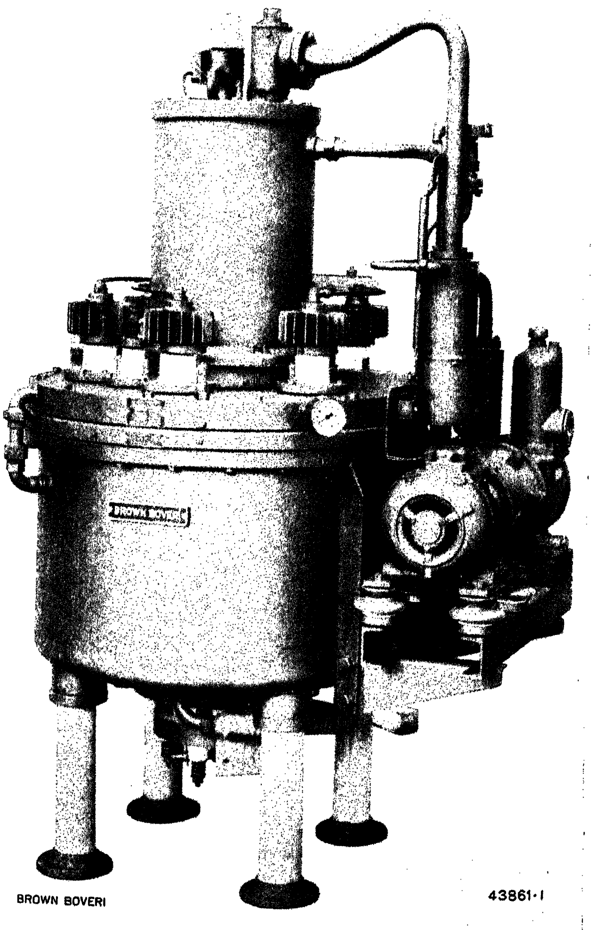


Fig. 82. — Mutator set with built-on vacuum-pump set, 184 kW, 230 V, 800 A.

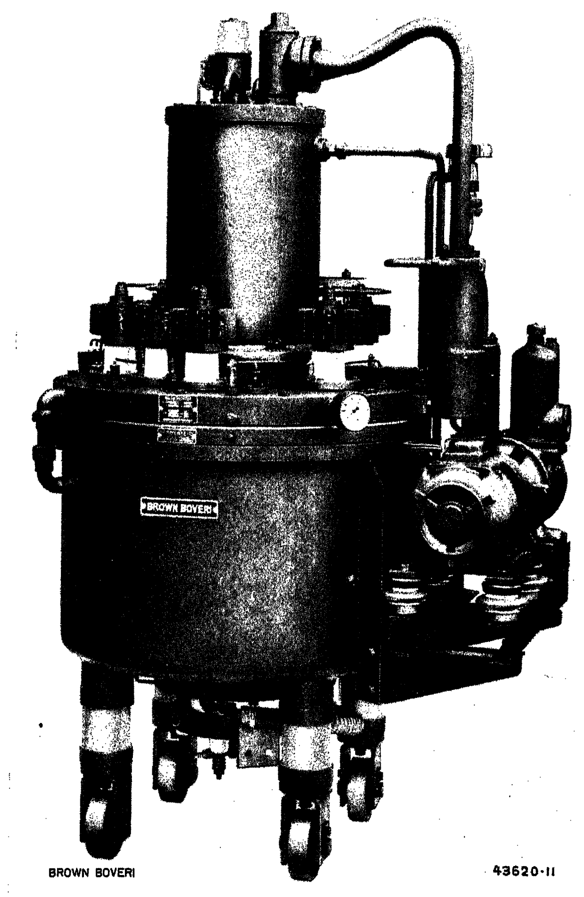


Fig. 83. — Mutator with built-on vacuum-pump set and supports with insulated rollers, 480 kW, 600 V, 800 A.

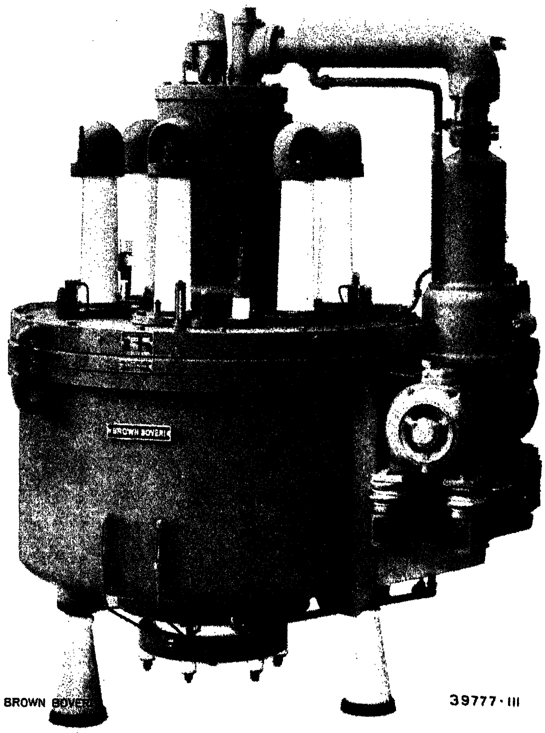


Fig. 84. — Mutator with built-on vacuum-pump set for the broadcasting station, Rome.

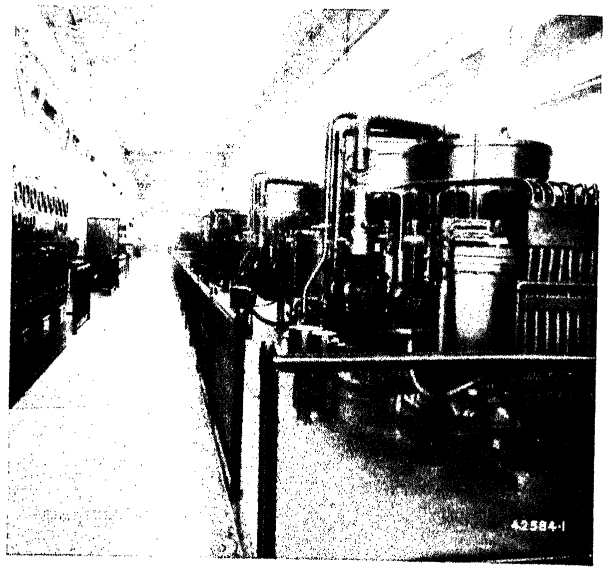


Fig. 86. Mutator plants Warfield I and II of Consolidated Mining and Smelting Co. of Canada.

service supervision and all trouble messages are reported here by optical and acoustical signals.

The *Letten Substation of the Town of Zurich Electricity Works* was equipped with two mutators, 1100 kW, 620 V for tramway-line supply and the Cie Electro-Mécanique, Paris our French concessionaries got an order for 8 mutators each of 2000 kW, 1560 V D.C. for Courtillère, Bessanges, Polerol and Moulinette Substations which are on the Tours - Bordeaux line, which the *Paris - Orléans-Midi Railway* are, now, electrifying.

Our last year's report mentioned

Fig. 85. — Mutator set for broadcasting station, China, with cooling by artificial air draught for both mutator and high-vacuum pump, 140 kW, 10,000 V, 14 A.

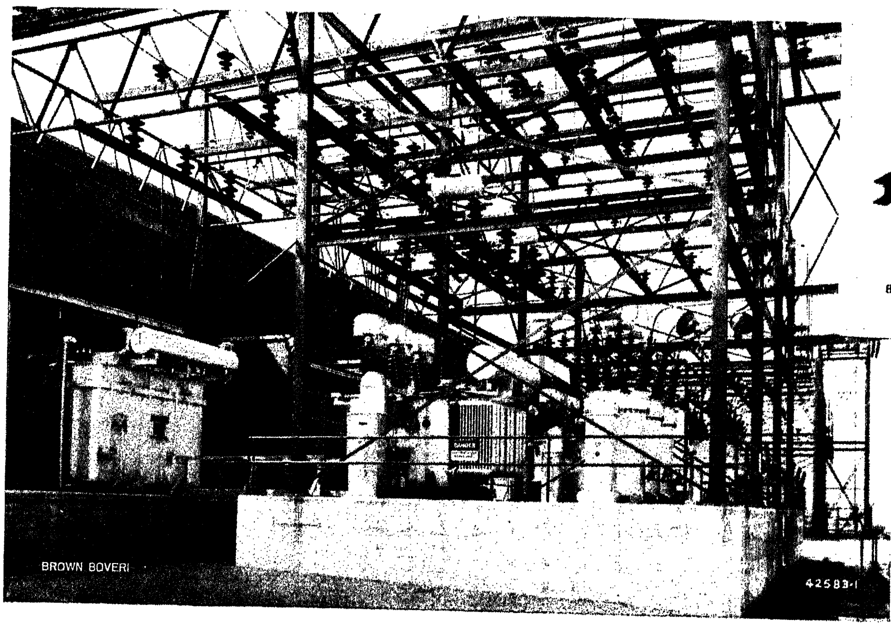


Fig. 87. — Outdoor station Warfield II of Consolidated Mining and Smelting Co. of Canada. Each set has an oil circuit breaker, regulating transformer and a mutator transformer.

mutators each of 1000 kW and 20 kV for the Rome-S. Palomba broadcasting station, these have now been put to work (Fig. 84). There are three 1200-kW

sets, 20 kV D. C. ready for starting service for the Sté Française Radio-Electrique in Paris and there are two units building each of 1500 kW at 12 kV for the broadcasting station of the U. S. S. R. the biggest built by us for this purpose, so far. Further the new, small air-cooled mutator (Fig. 85) which has met with such a welcome, in practice, has already been sold for broadcasting up to 12 kV in a plant in the Far East.

A big plant for aluminium electrolysis to which we already supplied eight mutators to give a total output of 27,500 A, is now being enlarged to take four of our mutators to produce, together, 20,000 A.

Fig. 86 shows the mutator plant of Consolidated Mining and Smelting Company of Canada, which already has 14 mutators of ours to deliver a total of 70,000 A. Fig. 87 shows the outdoor switchgear plant. Two big mutator plants for electro-chemical purposes, ordered last year from one of our concessionary companies are worthy of note. In one case, there are four mutators for a total of about 10,000 kW and 14,000 A on the D. C. side. A new kind of connection and design of the primary-side transformers had to be developed for this plant. The second plant has eight sets for a total of 80,000 A at 800 V D. C., three units working on a furnace system of 30,000 A. In all, there are two such systems, one being a stand-by. The plant is supplied at 6150 V. The mutator transformers have special connections.

III. OUR PRODUCTS IN INDUSTRY, TRADE AND AGRICULTURE.

A. DRIVES BY ELECTRIC MOTORS.

As the evolution in the design of our three-phase motors had reached a certain point of completion, at least as far as the units of low and average output are concerned, it was the turn of the *D. C. machines* to undergo a revision of design, the partial aim of which was to reach as close a degree of constructive similarity as possible with the three-phase motors of the same outputs and speeds and to make them as adaptable to the machines they are called on to drive as the latter have become in recent years.

The first D. C. machines to be revised were those of the 0·6 to 70 kW output range in which the standard design is also drip-water proof. There is a big opening on the commutator side, downwards, which gives access to the commutator and brushes. Further the brush rocker is designed to allow of rotating it, to make the changing of brushes easy. All these machines have both ample and strong ball bearings, constantly lubricated by grease, as is the case of the three-phase motors, so that the machines can remain for years in service without supervision.

Apart from the standard design with supporting foot and horizontal shaft (Fig. 88) the same motors

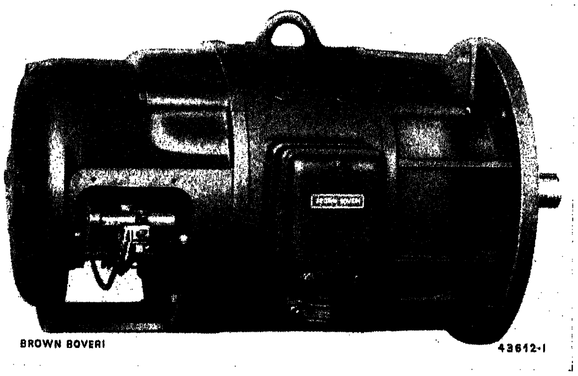


Fig. 89. — D. C. machine, 220 V, 6·6 kW, 1430 r. p. m.
Design with flange and feet, drip-water proof.

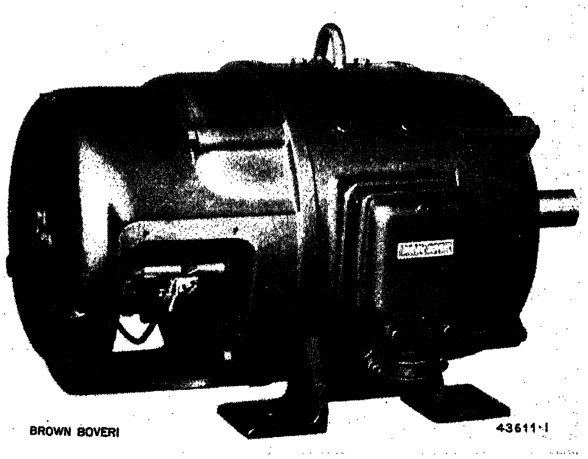


Fig. 88. — D. C. machine, 220 V, 6·6 kW, 1430 r. p. m.
With feet and in drip-water proof design.

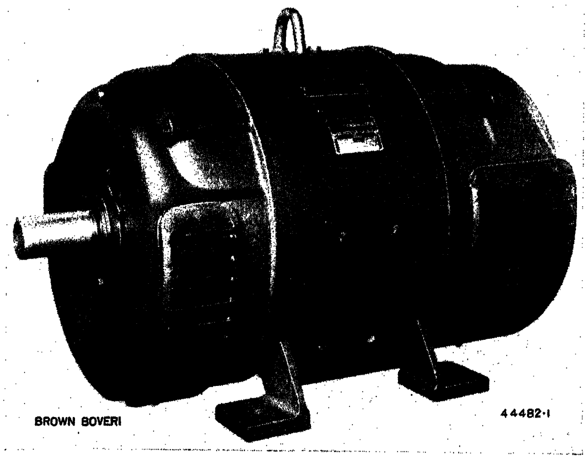


Fig. 90. — D. C. machine.
Wave-wash proof design.

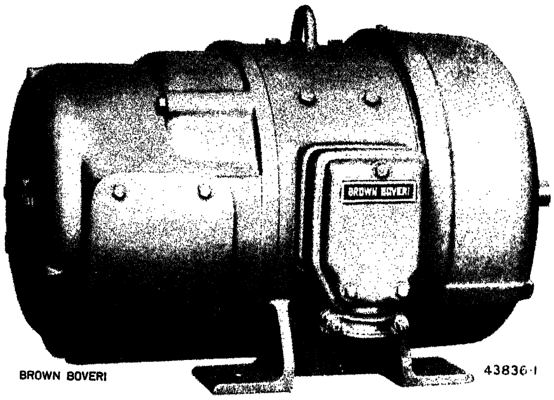


Fig. 91. — **D. C. machine.**
Totally enclosed, external fan and with foot, shaft horizontal.

are built with flange for close combination to industrial machines (Fig. 89) or for mounting vertically. Apart from the drip-water proof design, they are also built wave-wash proof (Fig. 90) and totally enclosed with surface cooling (Fig. 91).

There are suitable designs of terminal boxes to allow of chosing the best arrangement of leads, either brought in in pipes through glands or else composition-filled cable-end boxes; according to needs, these terminal boxes can be turned or put on at a slant.

As regards *special motors*, we have created new types of *loom motors*, forming a natural sequence to the successful development of the small three-phase motor. These new loom motors are characterized by their great adaptability to the needs of loom drive. The excellent results attained with cast aluminium rotor windings in standard motor types made it a natural consequence to use this design for the new loom motors, this all the more so as loom drive makes severe demands on the mechanical strength of the motors and, therefore, rotors are desirable which can stand up to the heavy vibrations and shocks inherent to these drives and which are as indestructable as it is possible to be. To this end, both shaft and ball bearings are designed to be very strong. Efficient external cooling of the motor housing allowed of keeping the temperature rise down, which is a very desirable feature. Both fans and air ducts are so designed that dust cannot collect and hinder the passage of cooling air. The high starting torque means rapid starting of the loom so that the slay movement is strong enough, from the first, and that the pick is properly made. Further, these motors are characterized by low power consumption under standard loom operation.

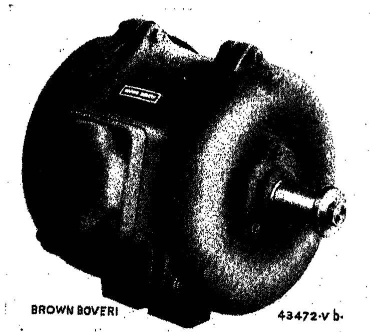


Fig. 92. — Three-phase loom motor with external cooling and surface for securing the motor. View from driving side.

Fig. 93. — Three-phase loom motor with external cooling and cradle to drive loom by belt. View from driving side.

Figs. 92, 93, 94 and 95 show the numerous uses to which these motors can be put, for the most varied arrangements of loom drives with looms of different kinds. Fig. 92 shows one of our loom motors of standard design and with machined mounting surface for securing it. Fig. 93 is the arrangement for combining with a cradle, to drive the loom by means of a flat belt or a rubber V belt. Fig. 94 shows the combination of the motor with a spring type of jockey pulley, with ball bearings, for belt drive when the shafts are close together and whatever the angle of belt pull may be. Fig. 95

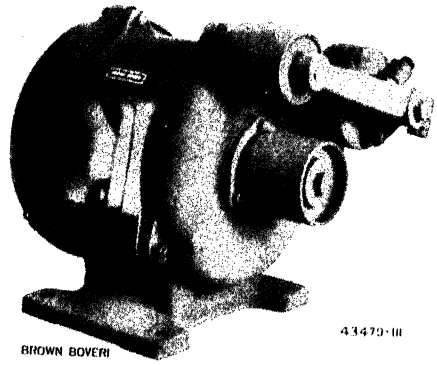


Fig. 94. — Three-phase loom motor with external cooling and built-on jockey pulley of spring type. (For belt pull from above.)

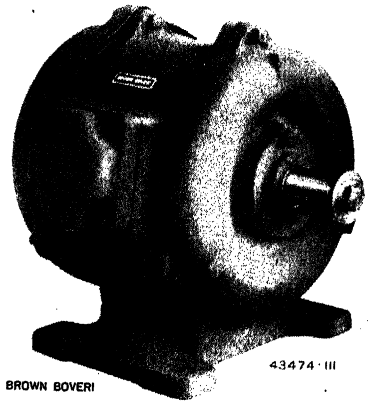


Fig. 95. — Three-phase loom motor with external cooling and foot bolted on. Seen from driving side.

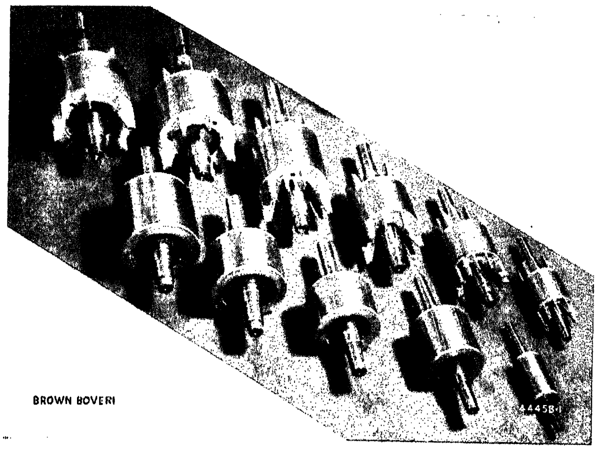


Fig. 96. Rotors with cast-aluminium winding.

shows the motor with bolted-on foot, allowing of lodging it on the top of the loom or any other textile machine.

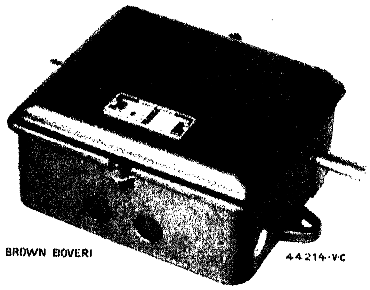


Fig. 97. — Loom switch with free shaft ends.

The use of the cast aluminium rotor winding was extended from the range of the smallest motors up to about 5 kW and for all numbers of poles. The improvement inherent to this type of rotor is thus made available for the whole range of outputs in question. Fig. 96 shows a number of such rotors of different sizes and numbers of poles. The rotors of the loom motors have no cooling blades as these units are only built to the totally-enclosed design.

The *switches* belonging to these motors were also redesigned. As Figs. 97 and 98 show, the switches in question are, now, totally enclosed and dust-proof. The housing and cover are of light metal, the cover being secured by two screws so designed that they cannot fall out; they assure a dust-tight closing.

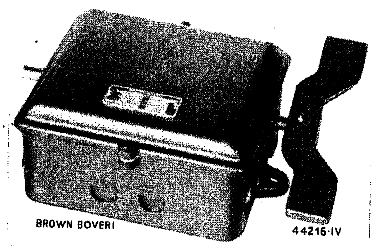


Fig. 98. — Loom switch for pedal control.

The switch design used in loom motor drives, which has given an excellent account of itself, namely the drum type switch with lubricated contacts for frequent switching, has been maintained. The fixed contacts can be used on both sides and, thus, require infrequent replacement only. The loom switch is built as a three-pole cut-out switch and as a three-pole reversing switch and with free spindle end to be connected to the control rod of the loom; it can also be equipped with pedal device for looms with controlled coupling. The switchbox is spray-water proof as well as dust-proof; it can be used not only in loom mills but in other services where a dusty atmosphere is to be expected, where spray water has to be reckoned with and where switching is of frequent occurrence.

The increased interest manifested during the course of the last year for *regulated drives of spinning and doubling frames* gave us an opportunity to deliver, to various countries, large numbers of these drives with the new *spinning regulator* referred to in last year's report. These drives have been most satisfactory. The adjustment, by means of

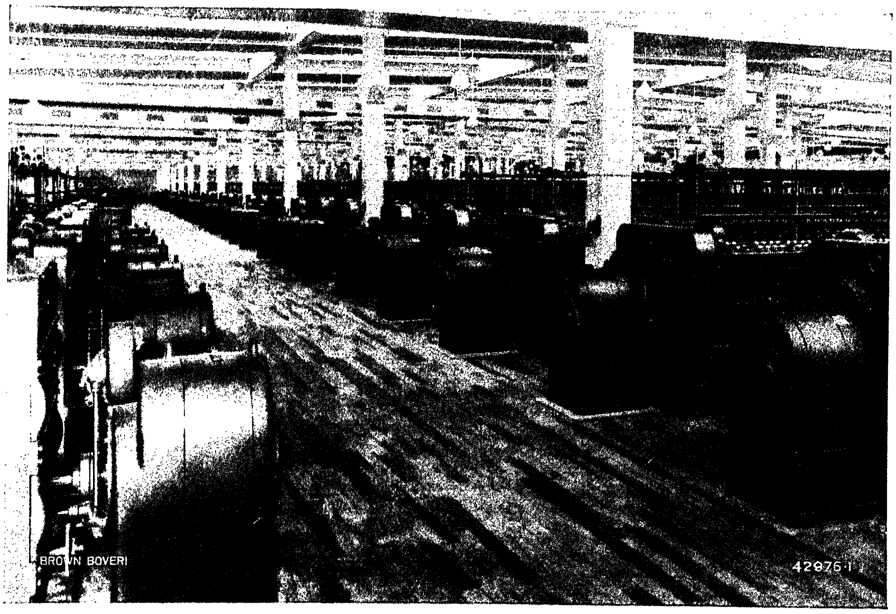


Fig. 99. — Cotton ring-spinning frames with variable speed drive by three-phase shunt commutator motors with spinning regulators.

Fig. 100. — Cotton ring-spinning frames with step-pulley drive by totally enclosed squirrel-cage motors with external cooling and built-on switchboxes.

a single key, of the regulated values is much appreciated. This allows of the spinning regulator being set easily without any adjustments of the excentric cams, so that the exact speed diagram is attained which is most suitable to the spinning and doubling frame driven and the yarn number worked to. Thus, our new spinning regulator, working together with our three-phase shunt commutator spinning motor, offers the highest degree of adaptability to the spinning process being carried out, makes for easy as well as efficient supervision and for the best utilization of the spinning and doubling frames used. Regulated drives of this kind can, even, be used to advantage in plants which produce only one kind of yarn as they encourage investigations into the possibilities of using other and higher spinning speeds and lead directly to better production and more competitive conditions. Fig. 99 shows a plant equipped with our motors and regulators, in 1936.

In cases in which it is thought advisable to do without the advantages inherent to variable-speed spinning, in order, for example, to keep first costs low, squirrel-cage motors can be used. We have developed a simple driving arrangement for mills of this kind, for belt drive over a *step pulley* and jockey pulley and using externally fan-cooled, totally-enclosed motors (Fig. 100). Both motor and driven machine are equipped with two-step pulleys of double width. The diameters are so chosen that the speed difference between the two steps is about 12 %. The cop bottom is spun at the lower speed and the upper part of the cop at the higher one. Compensation of the periodic variable thread tension is not possible, here. Thus, such extensive and manifold improvements of working process in a mill as are characteristic of the spinning regulator combined with the commutator motor are out of the question, here. Nevertheless, the number of thread breakages can be kept down to a moderate number during the starting period and the spinning speed as compared to ordinary line transmission drive, can be increased, which means increased production.

Apart from the special design for ring spinning frame drive, several other interesting applications have been found for the three-phase shunt commutator motor, in the course of last year. Thus, for example, for driving aluminium rolling mills, leaf bridges, braces and rotary presses. A noteworthy order was that for the drive of a rotary machine 34 m long with 15 printing sections, for the newspaper "Paris-Soir". Each unit is driven by a 50-H. P. three-phase shunt commutator motor with a speed regulating range of 1:5, combined with an auxiliary drive and overhauling clutch, through a noiseless chain. Regulation is, entirely, automatic with all interlocks and signalling devices requisite to perfect and reliable running. For the drive of the printed units when coupled together, there is a special relay to see that the load is evenly distributed on the various motors.

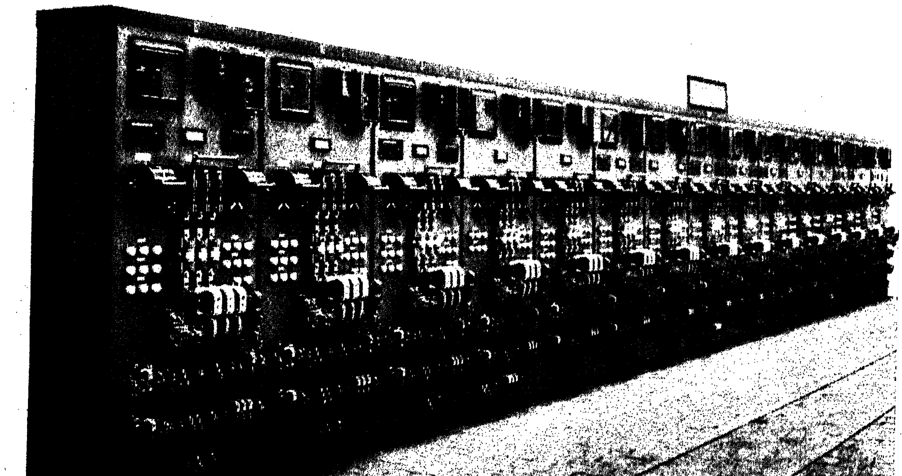


Fig. 101. — Paris-Soir printing plant, Paris. Switchboard for a rotary machine drive.

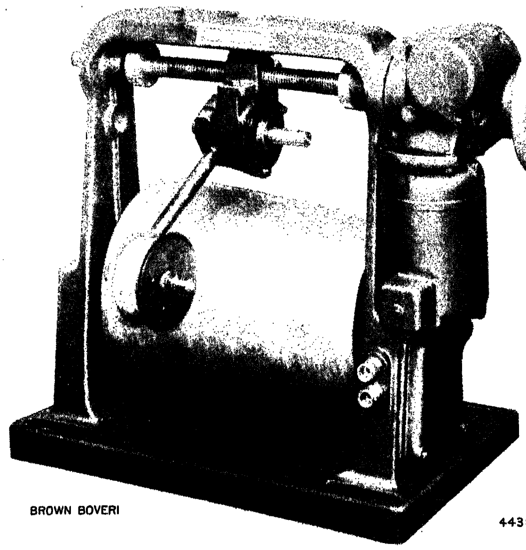


Fig. 102. — Frequency generator built into conical pulley for sectional drive of paper-making machines.

Fig. 101 shows the switchboard, 14 m long, of the said drive. In order to assure good supervision in service, all apparatus is mounted exposed and placed so as to be easily seen and got at, on the front of the board.

For the regulation of the paper draw in the *sectional drive of paper-making machines,* we use as mall three-phase generator on each driving set, which is driven through a conical pulley so as to allow of setting the exact speed as compared to the pilot speed (draw adjustment). As, in most cases, it is desirable that this generator and the drive should take up as little space as possible, we have brought out a new design in which the generator is lodged in the conical pulley. By suitable arrangement of a fixed stator and exciter winding the usual slip rings have been eliminated which reduces supervision to a minimum and increases reliability. The electric pro-

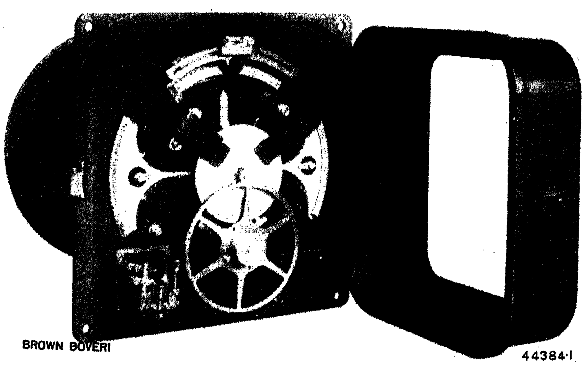


Fig. 103. — Draw regulator with built-in synchronizing relay.

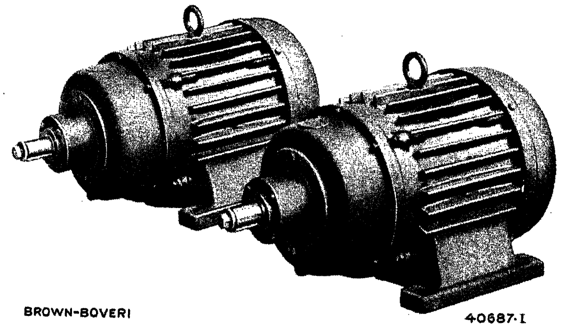


Fig. 104. — Three-phase geared motor, totally-enclosed design.

perties of this generator (Fig. 102) are so chosen that the electric differential supplied by it is sure to come into synchronism after the starting up of the driving set.

The requisite synchronizing relay which has only got to handle low currents has been built into the draw regulator (Fig. 103) which does much to simplify outer connections and reduces the costs of lodging the apparatus in the switchboard.

The field of application of our standard three-phase motors has been further widened by the re-designing of *geared motors* and *gears for motors.* Fig. 104 shows motors of this kind with planetary gear drives built by the v. Roll Iron Works in Clus, (Switzerland). The pleasing design and coaxial layout of motor and gear shaft are striking features, here. The gears are oil-lubricated and entirely shut off from the motor. The high degree of precision in the execution of these gear wheels makes the machine a suitable one for the severest of continuous-service requirements. The reduction ratio can be graded by suitable choice of the gear wheels, so that, practically, any speed required can be provided.

A special built-on jockey pulley is, now, used for three-phase motors driving through a

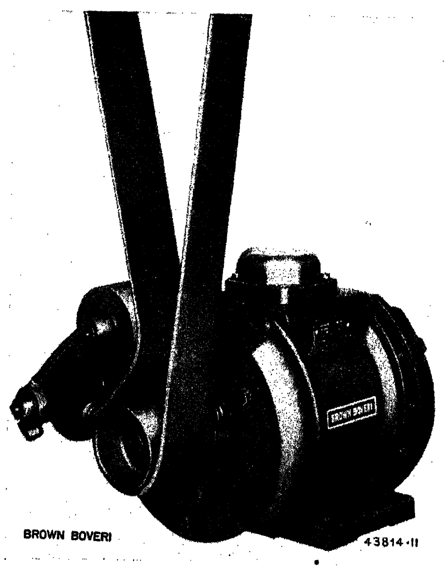


Fig. 105. — Three-phase motor, 2·2 kW, 1420 r. p. m, with built-on jockey pulley.

belt and where both the speed ratio is very large and the shafts are placed close to one another (Fig. 105).

The jockey pulley can be secured on the motor according to the position of the belt and what the sense of rotation may be. The spring, built into the housing of the jockey pulley, can also be adjusted so that the desired belt tightness can be set to. A safety device prevents the jockey pulley being thrown backwards when the belt is in process of being stopped.

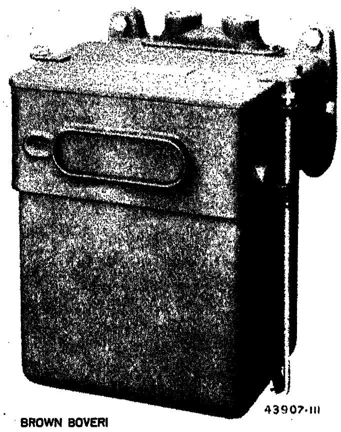


Fig. 106. — Switchboxes Types OMKe or OSM 4 d.

Design with double pipe branches.

Built-on jockey pulleys can be delivered with open and enclosed three-phase motors, of 0·1 to 6·6 kW. The design, which meets all the needs of practice, the easy mounting and low costs, should assure a wide field of application to the jockey-pulley motors in question.

In order to prevent a motor subjected to the *counter-current braking,* utilized in standard services of all kinds, from being started up in the opposite sense of rotation, we have developed a *reversing switch* to be placed on the shaft of the motor. When the speed passes through zero, a contact is opened and the circuit of the voltage coil of the brake switch is opened, which causes the latter to open. The contact of the reversing switch is sprung and is made of solid silver, so that it works reliably even when there is vibration and can be said never to burn down under frequent switching.

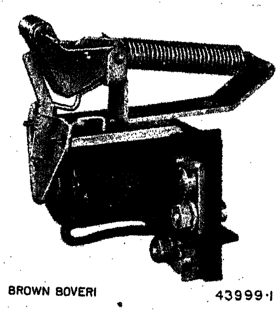


Fig. 107. — Fault-voltage tripping device for switchboxes.

In the case of small motors, when braking and starting periods are so short that the time lost for carrying out the switching processes would be felt, the contact of the reversing switch can be inserted on the current circuit of one of the motor phases. When the motor speed passes through zero, it is, thus, connected up as a single-phase unit and cannot develop any torque for rotation in the wrong sense. This allows of making quite sure that the motor will only be braked to a stop.

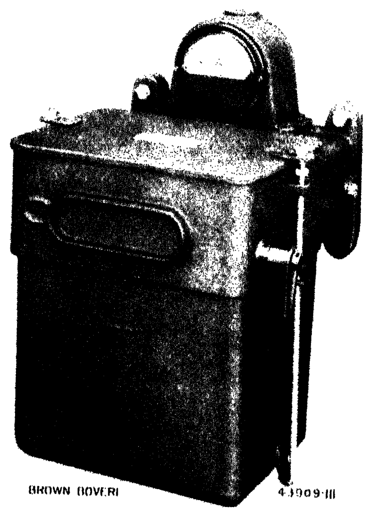


Fig. 108. Switchbox Types OH 4e or OSH 4 d.

Design with ammeter.

The line of our *motor-protection switches* with oil-immersed contacts has been extended by the addition of a new type for 64 A (Fig. 106). A new type for 125 A is being studied. These are, both, for hand and for remote control by coil; in the latter case push buttons may or may not be built into the switch housing. The design is, fundamentally, the same as the type described in last year's report. The switch has been made suitable for the most varied requirements and special demands by bringing out a number of special designs and by redesigning the connection parts for the bringing in of the leads.

To meet an increasing demand for efficient protection against dangerous accidental contact voltages which occur in electric plants, we developed a *fault-voltage tripping device* with spring operation (power-storage operation), which is designed to be lodged in several of our standard motor-protection switchboxes (Fig. 107). There is a very sensitive voltage coil one end of which is connected to the metal part to be protected (motor housing, for example) and the other to an auxiliary earthing

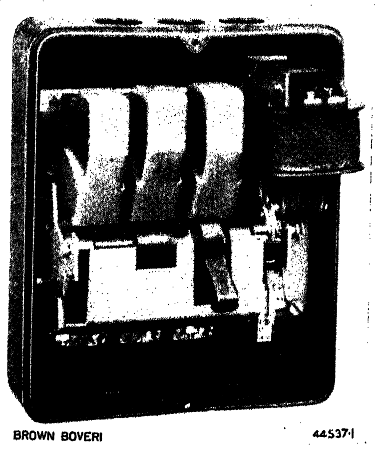


Fig. 109. — Switchbox Type NM1.

Fig. 110. — Double push-button. Rated voltage 500 V, rated current 4 A.

which it is easy to create. If, now, a voltage of 20 V or more appears on the metal body in question (due to a fault of insulation, for example) the coil frees a power-storage (spring) device which discharges its stored energy with great force on the tripping rod of the switch.

In spite of the smallness of the apparatus the whole device is insensitive to violent vibrations.

An original variation of the basic design of *star-delta motor-protection switch* has been brought out. This is for 40-A rated current and for both hand and coil control. Usually, with switches like this, combined with motor protection, a main switch and change-over switch are necessary, which means using three contactors in the case of remote control; here, however, there is only one contact system with ten contact pieces and this makes the apparatus compact and inexpensive.

A further advantage is that one single movement of the operating organ suffices to operate it and the transition from star to delta position is carried out independently of the operator according to a time which can be adjusted to. To this end, there is a clockwork, also oil-immersed, the running time of which can be regulated between about 3 and 15 seconds.

All the other organs of the switch (Fig. 108) correspond to those of the series of motor-protection switches, with oil-immersed contacts, which were mentioned in last year's report and has now been enlarged. Our well-known directly-heated thermal releases are used, here, as well. The reliability of these releases has been testified to by the successful installation of hundreds of thousands of them. The thermal releases are inserted straight on the phase current of the motor, in the switches in question, so that the said motor is not only properly protected when running but also during starting.

The increasing demand for a competitive and reliable *motor-protection switch* for *low current ratings* caused us to bring out a new type (Fig. 109) both for hand and for remote control.

This very small switch has a housing of insulating material in the base of which there are apertures to allow of introducing armoured pipes or glands for bringing in the leads. The interior design is very simple to follow, despite the compactness of the apparatus, and contacts as well as thermal releases are very accessible. The latter, like all our thermal releases, are directly heated, an innovation, however, is an additional bi-metallic element which so influences the tripping device that the switch continues to trip at the current to which it is set, even when there are changes in the external temperature.

In the design for remote control by coil, the housing is a little bigger; control can, here, be effected through a remote push-button or, if so desired, by the switch lever, as in the case of hand control, the said lever serving to show, at the same time, whether the switch is open or closed.

This small switch can also be equipped with the fault-voltage tripping device as protection against dangerous accidental contact voltages and it can then be used as a station switch for small plants in which protective earthing connection cannot be carried out.

There are many variations to the design of this switch to meet a multitude of requirements. The countersunk mounting in switchgear panels is both simple and pleasing.

For remote operation of this switch, as well as of the other small motor-protection switches for remote control built by us, we have developed a small

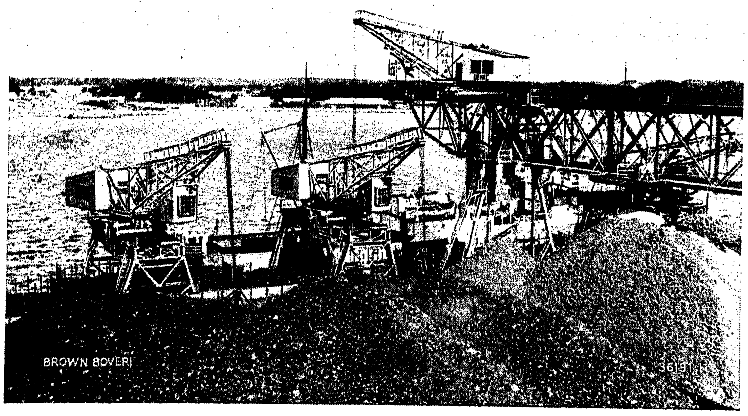


Fig. 111. — View of the coal and ore-loading plant of the Helsingfors Magasins A/B. Mechanical part delivered by Messrs. Demag A.-G., Duisburg.

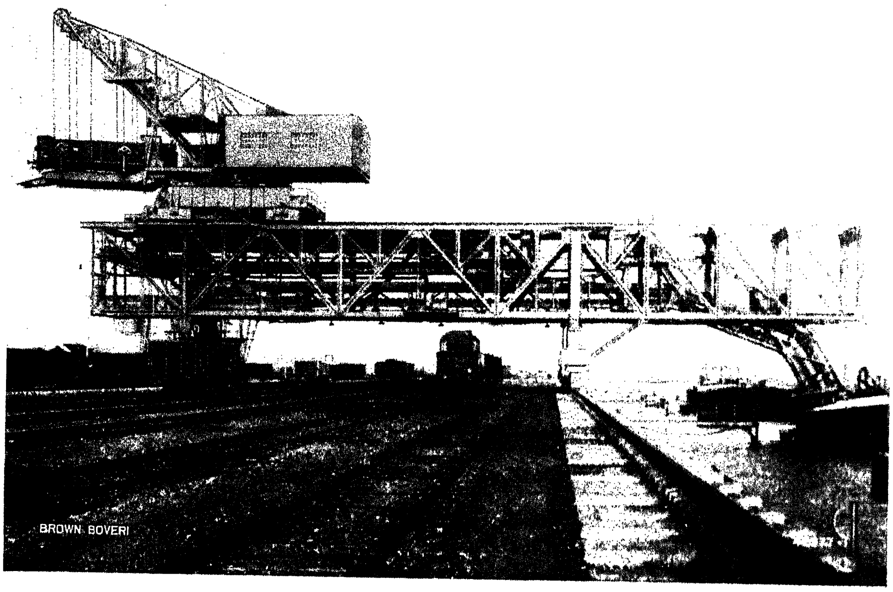


Fig. 112. — Truck tipper in the coal-handling plant of Born, belonging to the Dutch Railways.

double push button (Fig. 110). The housing thereof is also of insulating material with an opening to introduce an armoured pipe or gland. Red and black colours allow of distinguishing the push-buttons.

Our *hoisting-gear equipments* with single-phase commutator motors continue to give an excellent account of themselves and this has meant gratifying repeat orders for us. The special connections developed by us have proved so successful in the case of loading and unloading plants that a not inconsiderable increase in the former loading capacity of the said plants has been achieved as compared to what can be attained with three-phase induction-motor drive, this over and above the well-known advantages of our single-phase commutator motor drives, namely:— starting without losses, far-reaching speed variation, electric braking, low power consumption.

We had the opportunity to deliver to the *Helsingfors Magasins A/B, Helsingfors* (Finland) the electrical equipments for two high-power loading bridges. These clients have had similar equipments of ours in service for some years and been most satisfied with their performance. These bridges are, one, for quay work and, one, for storage-site work; the hoisting and closing mechanism of each is equipped with a single-phase commutator driving motor about 50 kW, with the requisite control gear of the latest design in safety brake-lowering connection. The other drives, such as rotating mechanism, crane and crab-travelling mechanisms, and that for bridge-displacement are provided with three-phase, induction motor drives with special connections created specially for this plant, to meet the different safety requirements imposed.

The drives, which call for very frequent switching, as, for example, 400 switchings per hour and more, are controlled by cam-type controllers with hammer-type contacts. We have mentioned this interesting apparatus on several occasions, in these reports. It can stand up to very frequent switchings and calls for very little attendance.

Our electro-hydraulic thruster has been used throughout instead of the former brake-lifting electro-magnets. This device has met with great success and has been described here in former yearly reports. Fig. 111 shows a loading bridge and two portal cranes of the Helsingfors plant.

In our report of the year 1935, we drew attention to our new *sub-synchronous braking connection with reversed phase* and referred to the different advantages inherent to this connection as compared to earlier ones with three-phase induction motors. In the meantime, we equipped a whole series of plants with this new control system; the results have been most satisfactory and fully up to expectations. One of the most important installations is the coal handling plants in Born (Holland) Fig. 112. This coal port is equipped with two truck-tipping bridges, namely: — a truck-tipper which can develop 45 tons and is composed

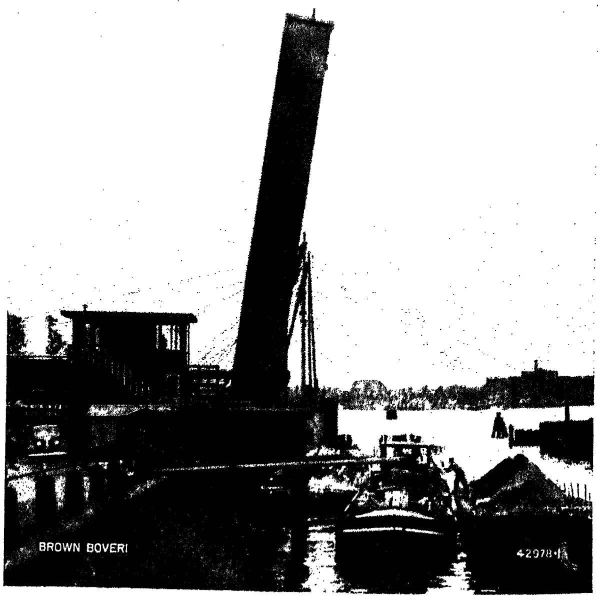


Fig. 113. — View of the rolling leaf bridge at Oosterdokslui, belonging to the Dutch Railways.
Bridge open.

of a fixed gantry carrying the travelling mechanism (mechanical equipment by Demag A-.G., Duisburg) and a 45-ton truck-tipper composed of a moving gantry on which are rails on which the slewing crane runs (mechanical equipment by A.-G. J. Pohlig of Cologne).

The powerful hoisting gears of these tippers can — as shown in Fig. 112 — raise and tip full railway trucks with their 20-t load. It will be obvious that to move weights of this magnitude a control system must be used which not only allows the driver a wide range of speed variation but gives him complete and delicate control of the movements at all times. Careful reflection led to the adoption of our new super and sub-synchronous braking connection, with reversed phase. There is no free-fall position with this connection and it gives speed regulation over a wide range and allows of very slow movement of the load, under electric braking.

A rolling leaf bridge was put into service, last year, for the Dutch State Railways, at Oosterdokssluis, Amsterdam. This bridge of the latest design is shown in Fig. 113.

This leaf bridge has a total length of about 35 m and weighs about 510 t. The winding gear for the leaf movement is driven by a *three-phase shunt commutator motor* of about 20 H. P. with a wide range of speed variation, which is necessary in order to bring such heavy weights to a slow stop

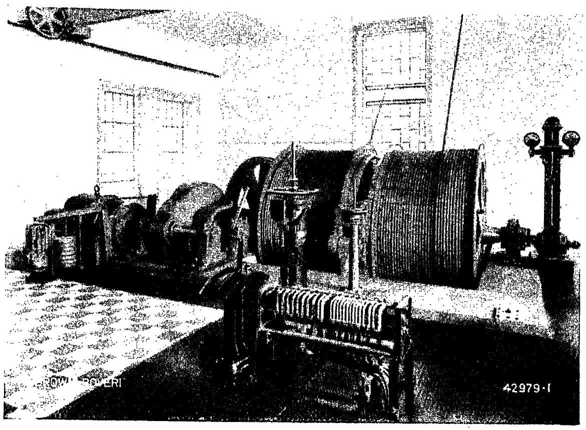


Fig. 115. — Cia. das Minas do Carvao de San Pedro da Cova, Porto. View of the mine hoist with single-lever control and electro-hydraulic thruster as brake raiser.

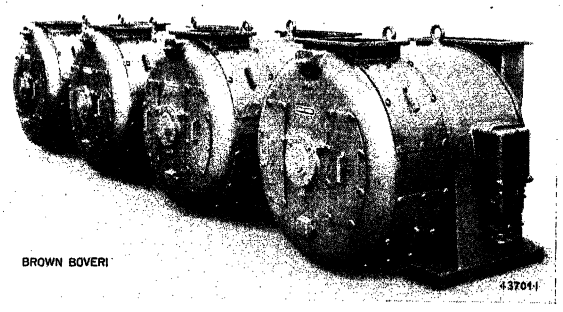


Fig. 116. — Externally-cooled three-phase shunt commutator motors 91/18·4 kW, 750/150 r. p. m., 220 V, 50 cycles.
Drive of drilling derricks.

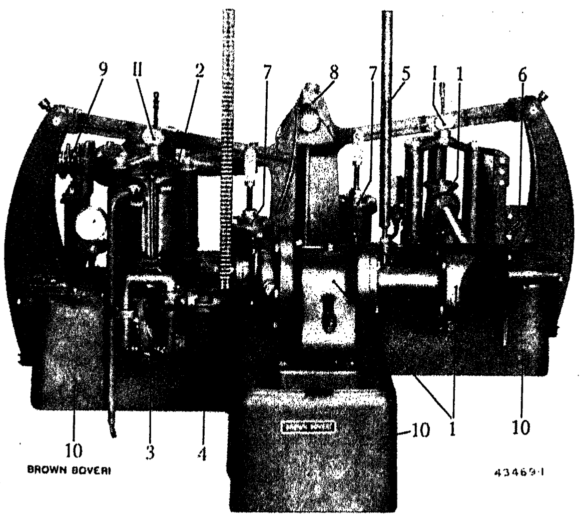


Fig. 114. — View of the oil-pressure travel regulator.

I. Actual-speed piston.
II. Specified-speed piston.
1. Gear of actual-speed piston.
2. Electric motor of specified-speed piston.
3. Oil-circulation valve.
4. Control valve T of the specified-speed piston.
5. Control rod of valve T on specified-speed piston.
6. Control curve of valve S of actual-speed piston.
7. Power storage.
8. Mechanical differential-gear.
9. Pneumatic brake-pressure regulator.
10. Bed plate designed as oil tank in which gear pump and centrifugal pump are lodged.

in their end-travel positions and especially to allow of the bridge coming softly to rest in its lowest position. The preference was given to a shunt commutator motor as it allows of attaining the desired speed regulation without losses and simply, without requiring a big number of auxiliary safety and control devices. This type of motor should find an increasing field of application in moving-bridge equipments like this one.

We desire to say that we have developed an *oil-pressure travel regulator.* A detailed description of the new oil-pressure travel regulator will appear in our March Number, 1937, so that a summary description will suffice, here. The object of the apparatus is to exercise continuous control on the speed-curve characteristic specified for and to impose the said characteristic on those hoisting gears in which there is no sympathetic connection between control-lever displacement and speed of the cage, this happens in the case in three-phase hoisting equipments. Our travel regulator is independent of the centrifugal governor and friction drives and has no similarity to the flow regulator of steam-driven hoists; it is based on the following principle:— A gear pump and a centrifugal

pump drive oil under pressure below two spring-weighted pistons which are connected through a common differential gear. The gear pump is driven by the hoisting engine so that its influence on the differential mechanism is proportional to the "actual" speed. The centrifugal pump is electrically driven and runs continuously. Its effect on the differential mechanism depends on the "specified" speed, a result attained through throttling an oil circuit, more or less in accordance with the displacement of the hoist cage. If both forces acting on the differential are equal, the latter remains in equilibrium; if the "actual" piston predominates the differential moves to actuate the brake pressure regulator in the brake-applying sense and this as long and as strongly as is necessary to bring the "actual" speed back to the "specified" speed. If the "specified" speed side predominates, the differential moves in the opposite sense, but in this sense it swings free and does not affect the brake regulator as no application of brakes is desired. The travel regulator watches over the travel in absolutely reliable manner, and regulates down to the lowest speeds for coming to a landing station. It prevents, under all circumstances, that the cage should come up to the landing stage at a speed greater than that laid down for coming to a stop (no over-winding).

Fig. 114 shows our travel regulator on a plant so equipped by us.

To drive this mine hoist, there is a three-phase induction motor, 170 kW at 750 r. p. m. controlled by a cam-type controller with hammer contacts and individual spark blow-out. The life of this type of contact is considerably greater for service conditions than is that of friction-surface contacts. There is a single-lever control pedestal to actuate the controller in question, which is seen clearly in Fig. 115. This illustration also shows the electro-hydraulic thruster (on the extreme left) used here for brake raising on the holding brake.

Among electrical equipments for hoisting plants built in 1936 by us mention may be made of that of a hoisting plant with a Koepe pulley of 5·5 m diameter to handle a net load of 4000 kg at 10 m/s hoisting speed, from a depth of 1250 m. A three-phase induction motor of 500 kW at 2000 V, 50 cycles is used and the oil-pressure travel regulator, just described is also fitted.

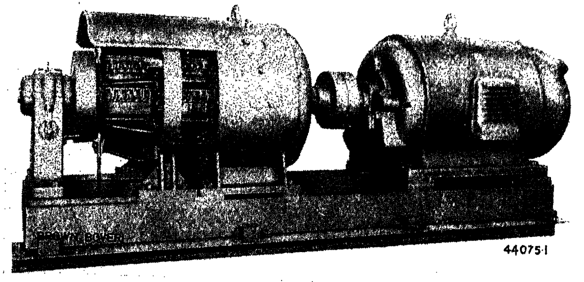


Fig. 117. — Multi-site welding converter. Generator 4000 A, constant voltage 40 or 50 or 60 V, 1500 r. p. m. Motor 500 V, 50 cycles, 265 kW.

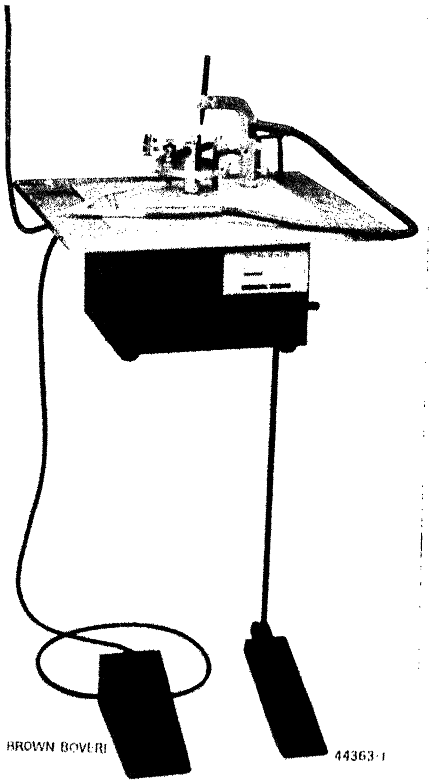


Fig. 118. — Soldering and welding apparatus Type TLsk 3, ready for service, countersunk mounting.

For the first time, we used shunt commutator motors in a *boring plant for the electric equipment of 14 drilling derricks.* The plant has, now, been put to work and has given great satisfaction. The motors are flame proof with external cooling (Fig. 116) and for 90/18 kW continuous rating at 750/150 r.p.m.

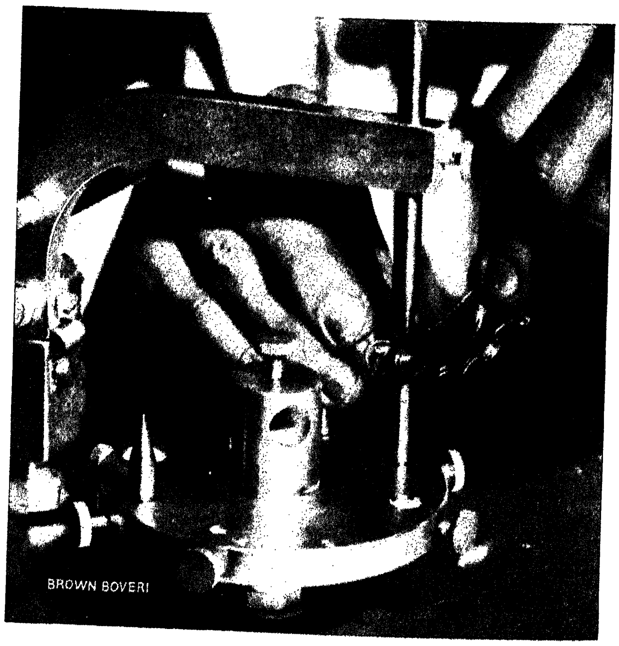


Fig. 119. — Soldering a hook to a dental steel plate by means of the soldering and welding apparatus, Type TLsk 3.

They are started up and their speed regulated by brush displacement, and braked in this way, through a mechanical remote-control arrangement from a control pedestal located in the drilling operator's post. All the severe service requirements were met by these motors without accessory equipment being necessary, a great advantage as space was restricted.

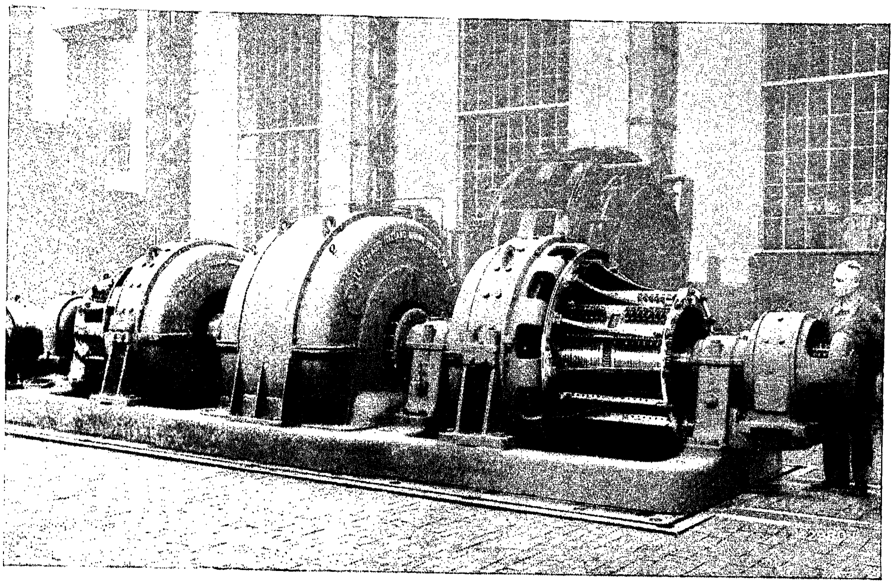


Fig. 121. — Two D. C. generators, 750 kW, 0—100 V, 7500 A, 600 r. p. m. coupled to synchronous motor, exciters overhung.

B. ELECTRIC ARC WELDING.

Apart from the welding machines and transformers developed by us for D. C. and A. C. arc welding each for one welding site, our 40-V plants for welding on several sites at once (multi-site welding plants) with smooth regulation of the welding current have met with ever-increasing success.

The *Ateliers et Chantiers de Penhoet* in *St. Nazaire* already possessed three welding central stations to supply their extensive welding shops, with a total welding current of 16,000 A at 40 V supply voltage. Quick-acting over-current protection regulators were introduced with very great success to all the three welding central stations.

The duty of these regulators is to cause the two other stations to contribute power automatically to the third one if it happens to be momentarily overloaded. As, further, the location of the connecting point of the welding sites to the distributing systems varies very much, these clients ordered from us a fourth and portable welding set, in order to avoid considerable transference of welding power. This new set is for 4000 A. The portable station is mounted on a railway truck 11 m long and is always connected in parallel to whatever fixed supply system is to be supported, namely the one which carries a heavy load, on account of having a great number of welding sites working at the same time. This portable central station, like the other ones, has automatic voltage and over-current protective regulation. It brings the total welding-current output up to 20,000 A sufficient for the supply of 310 welding sites. Fig. 117 shows the multi-site welding converter of the portable station.

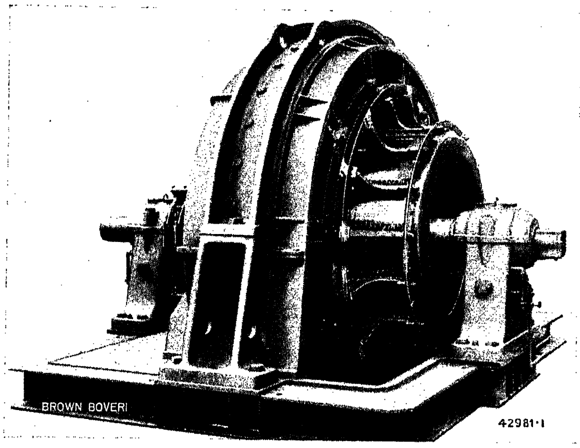


Fig. 122. — Six-phase rotary converter, 230—410 V, 6000 A, 48/51 cycles, 360/383 r. p. m.

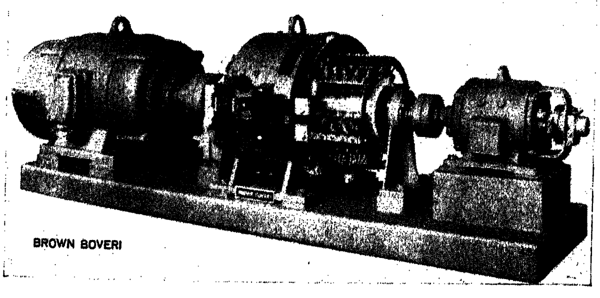


Fig. 120. — D. C. generator 6—14 kW, 6—14 V, 1000 A, 1450 r. p. m. Design with two shaft ends coupled to three-phase motor and exciter.

While on this subject we would say that we have developed a *small soldering and welding apparatus* for workshops, for dentists, opticians, jewellers and precision mechanical work (Fig. 118). This apparatus gives smooth regulation of the welding current between 80 and 650 A at a voltage of a few volts. Regulation is carried out without contacts on the windings or resistances, which is very

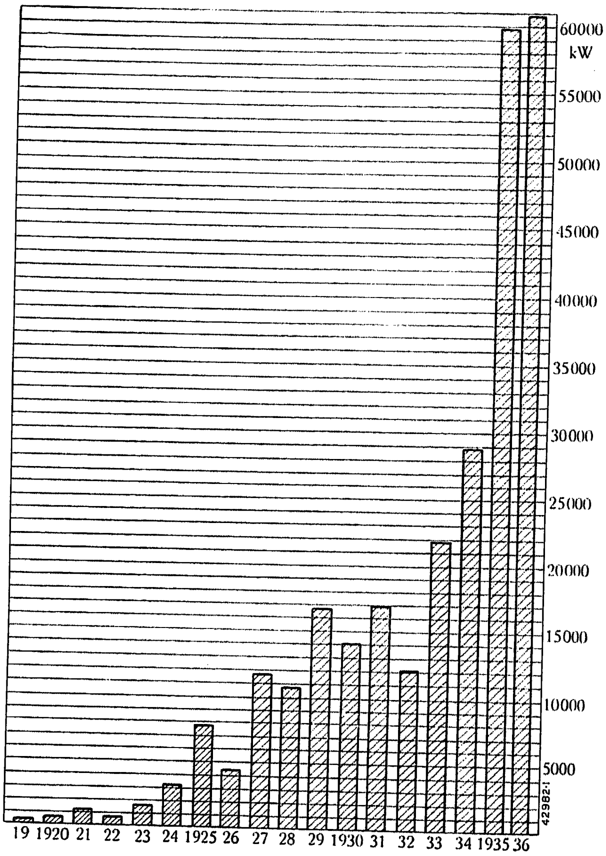


Fig. 123. — Power input of all electric furnaces built by the Brown Boveri Concern.

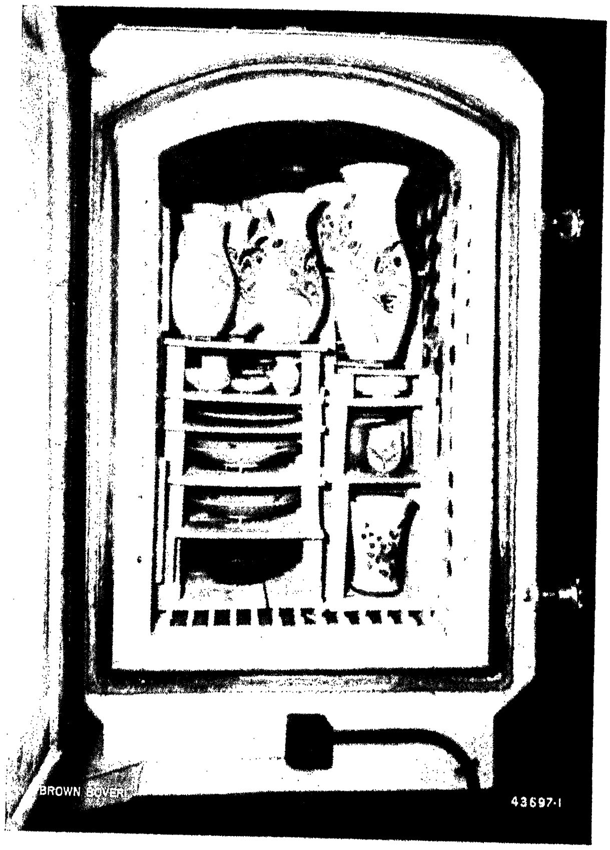


Fig. 124. — Biscuit and enameling firing electric furnace for pottery and decorative firing of porcelain. Max. temperature 1000° C, furnace chamber dimensions 600 × 900 × 900 mm, furnace capacity abt. 0·5 m³, input 25 kW, 500 V, 50 cycles.

advantageous. The weight of the apparatus is 18 kg. The current can be regulated smoothly over the entire range mentioned. The different electrodes can be applied on a small rotary table, this quickly and without any difficulty. The requisite tools for soldering and welding as well as a pedal-controlled switch can be delivered. The apparatus can be connected to the lighting circuit; it allows of soldering gold between 18 and 22 carats and of welding rustless wires or fine sheet metal such as are being increasingly used, to-day.

C. HEAVY-CURRENT MACHINES FOR ELECTRO-CHEMICAL PURPOSES.

We have developed new designs in this field (Figs. 120). These machines of welded construction are very compact. A number of heavy-current generators have been built during last year for electro-chemical plants, for 4000, 8700, 11,500 A and 15,000 A. Fig. 121 shows the last machine mentioned built together with its driving motor. Fig. 122 shows a rotary converter, built by one of our concessionaries, for 2460 kW, 383 r.p.m., 6000 A, 410 V.

D. ELECTRIC FURNACES.

The number of furnaces delivered increased considerably during last year. This favourable development is, certainly, due, in the first place, to the far-seeing metering policy adopted by many power-producing

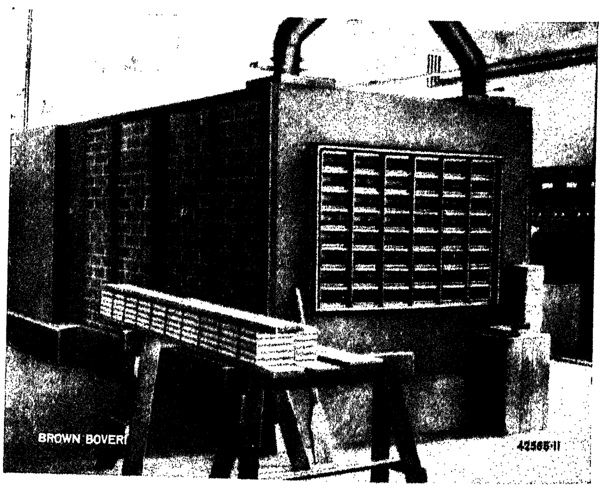


Fig. 125. — Electric furnace of multi-channel, push type for enameling firing of wall tiles. Max. temperature 960° C, input 70 kW.

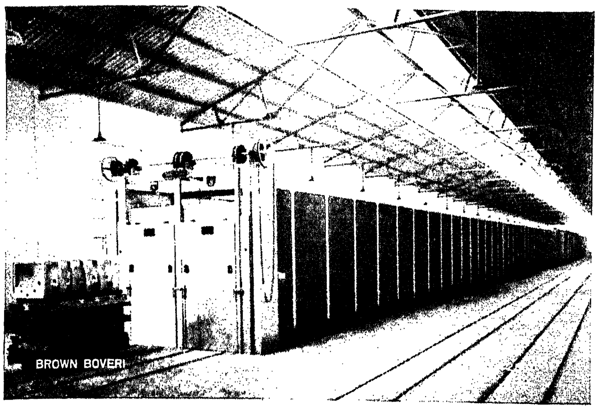


Fig. 126. — Electric double-tunnel furnace for firing sanitary ware, fire clay objects and vitrous china. Max. admissible temperature 1400° C, length of furnace 110 m, production 3800–7500 kg in 24 hours.

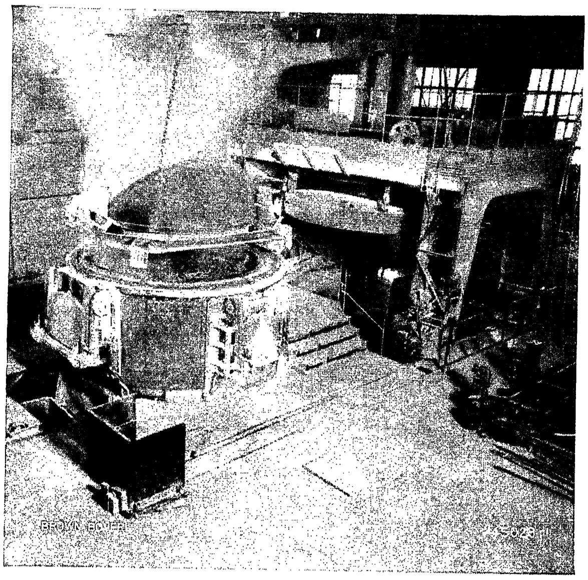


Fig. 128. — Arc-melting furnace for steel, to take a charge of 15—18 t, with removable cover and grab-charging.

companies, which saw in the big calorific power consumer a welcome outlet for current and one which only took active power and was characterized by only moderate load-peak requirements. The development of the electric furnace in the last year is, however, also due to the success our designs have met with. Fig. 123 gives a graphic illustration of the number of furnace plants built by our concern since this branch was developed, this in each calender year. It is seen that the years of the industrial crisis caused some retardation but no stoppage of activity.

It was, chiefly, the ceramic industry which offered new fields of application to the electric furnace in the past year. A furnace of 0·5 m^3 available interior heating area and for 950° C was built for biscuit firing and enameling firing of pottery and the firing of enameled colours on porcelain; this unit differs from the usual ceramic furnace in different respects. By means of a very special distribution of the heating power in the floor and side walls it was found possible to attain uniform distribution of temperature while dispensing with the usual heating of the furnace door and back wall. The heating elements are laid in half-open slots in the refractory lining and, contrary to a common conception, they have absolutely no deleterious effect on the ceramic charge. This type of furnace has already been built for several plants and has given general satisfaction. Fig. 124 shows one of these furnaces, charged.

For the enameling firing of wall tiles, a continuous-push multi-channel furnace was built for a Swedish firm with 48 channels (Fig. 125). This unit is dimensioned for a production of 6900 tiles in 24 hours and a burning temperature of 960° C. Special devices allow of a high degree of heat recuperation so that the kWh-consumption per net kg is only 0·213 kWh/kg. The scrapped material on account of breakage was about half what may be expected from a coal-fired furnace and the scrapped material on account of poor quality was reduced from 20% to 7%. The furnace is, therefore, very

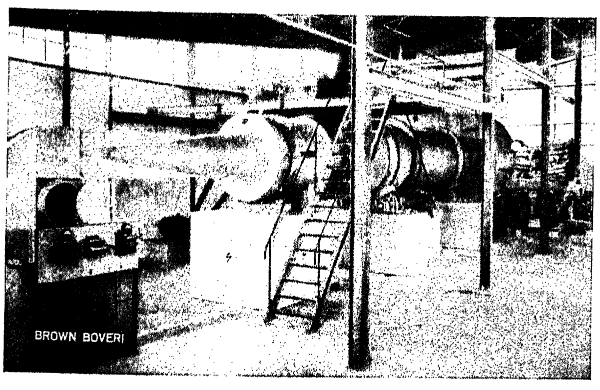


Fig. 127. — Electric air heater with fan plant for a drying drum of the Büttner type. Max. power input 1500 kW at 660 V three-phase supply.

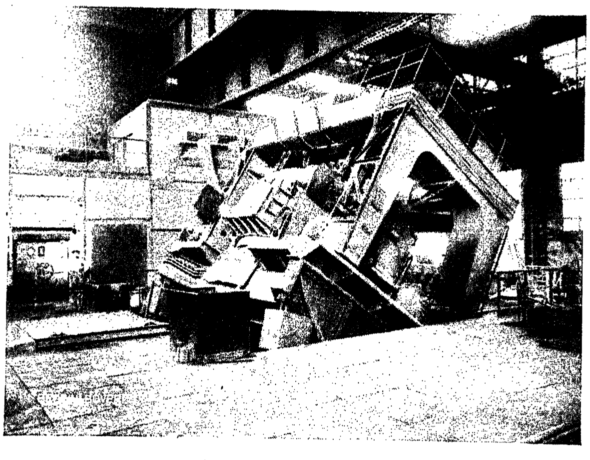


Fig. 129. — Arc-melting furnace for steel, to take a charge of 15—18 t, with removable cover and grab-charging.

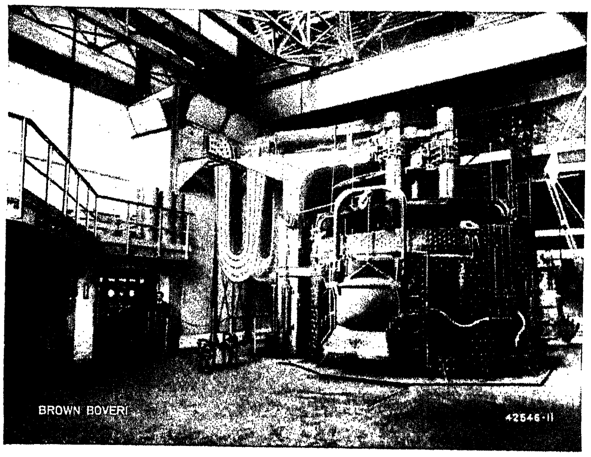


Fig. 130. — Biggest arc-type melting furnace on the Continent. Brown Boveri design. For melting and refining steel. Charge 30—36 t. Maximum power input 5000 kW.

economical both from the point of view of heat consumption and of production quality. For this reason, the same firm has ordered a second one and is considering buying a third unit in the near future.

The double tunnel-type furnace built by Tecnomasio Italiano Brown Boveri, Milan, for *S.A. Materiali Refrattari, Milan* for the high-temperature firing of sanitary fire-clay objects has been put into service and has met all guarantees as regards heat consumption and quality of products. The furnace, shown in Fig. 126, is built for 1400 ° C and a max. production of 37 m^3/24 hours for a gross charge of 350 kg/m^3.

The tunnel-type furnace mentioned, here, last year, for biscuit firing and high-temperature firing of hard porcelain, for the *Porzellanfabrik* in *Langenthal* (Switzerland) designed to take the entire production of the works (which, up till now, was handled by six round furnaces), was erected last year. It was started up towards the end of 1936.

There is more attention being paid, of late, to the use of electrically-generated heat for various drying processes. We would mention an *air heater* of 1500 kW to heat up 6000 m^3/h of air from the room temperature to 650 ° C. This hot air is used to dry fruit residues in a rotating drum. As shown in Fig. 127, the air heater was so designed that it could be completely lodged in the plant. It has worked for one season and shown itself extremely adaptable to production conditions.

Further, our bright annealing furnaces with Grünewald pots have found some interesting applications. Horizontal chamber furnaces have, up till now, been used exclusively for the Krupp nitriding process. The pieces treated have to be placed in the furnace in sheet-metal boxes, into which ammonia gas is led. As it is impossible to make these boxes tight, the consumption of the said gas is very great, during the 80-hour duration of the process. The Grünewald annealing pots allow of eliminating this drawback, especially when the pieces treated are cylindrical. The Locomotive Works, Winterthur ordered a first Grünewald bright annealing plant for the nitriding of bushings of airoplane motors. This furnace has a pot capacity of 800 mm height and 600 mm diameter, 36-kW power consumption, highest service temperature 850 ° C; ordinary service temperature for nitriding 500—550 ° C.

Figs. 128 and 129 show arc furnaces of our latest design with removable cover and supply by a grab device, for a 15—18-t charge. Our biggest arc furnace for a 30—36 t charge is shown in Fig. 130.

E. THE ELECTRIC BOILER.

Electricity is cheap as a source of power, but expensive as a source of light. For the latter purpose, however, it is an extremely suitable agent indeed and this explains its rapid expansion in the field of lighting. To utilize electricity for heating purposes is very extravagant from the point of view of financial outlay, as the equivalent amount of heat can be obtained from various fuels at a fraction of the cost. Here again, however, the exceptional adaptability of electricity to the purpose has been a preponderant factor in the case of a number of small apparatuses, such as irons, hot cushions, tea kettles, cooking ranges, hot-water accumulators, etc. A far-seeing metering policy applied by

Fig. 131. — Element from a Brown Boveri water-jet boiler.

The resistances are formed by the water jets of small section and considerable resistance. It is thus a typical high-voltage boiler. There must be no spraying when the jet impinges on the electrode and this is assured by a patented Brown Boveri electrode design. The boiler is an all-metal unit without built-in ceramic parts.

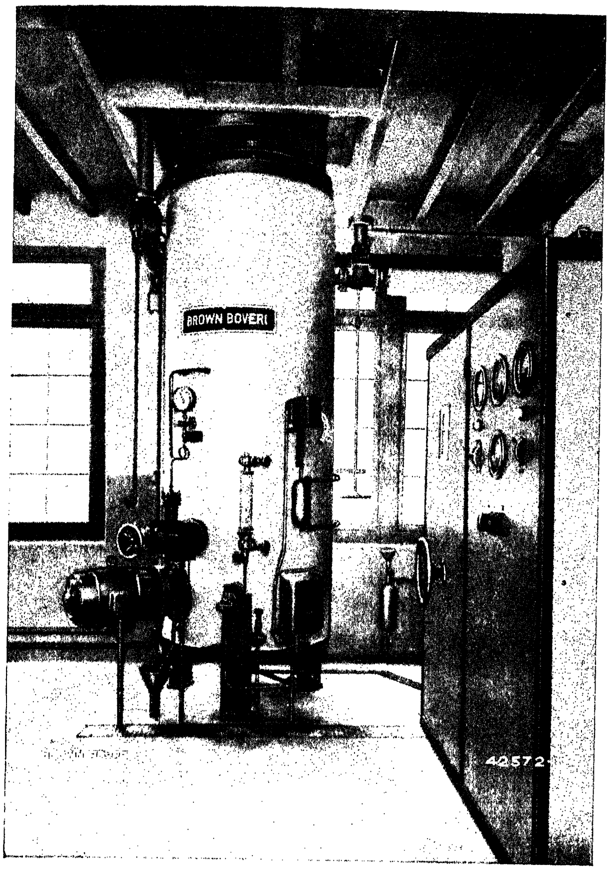


Fig. 132. — High-voltage electric boiler for 800 kW, 4000 V placed in the Fédération Laitière du Léman, Vevey (Switzerland).
The circulating pump is seen as well as the regulating apparatus for water level and steam pressure.

the electric power supply companies has assisted the development of electric household apparatus, the object pursued being to utilize power at the low-load periods of the day. In recent years, big quantities of electric power have been utilized to generate steam and hot water, in industrial and heating plants, in countries which possessed a big hydro-electric power supply. This field of consumption of electricity was opened up during the recent years of severe industrial depression, when there were considerable amounts of power available for which no application could be found and which were, finally, disposed of at a very low tariff, determined by the cost of coal fuel, at the time. Delivery of electric power to electric-boiler plants is generally made on the condition that the supplier can cut off power, at any time, after giving preliminary warning thereof, when a more advantageous outlet for the said power is available.

For this reason, the combination of an *electric boiler and a Velox steam generator* is very advantageous. The latter can be started up within a few minutes at small expense or, alternatively, cut out. The possibility of having a type of steam boiler which can be put into service and cut out of service after a short running time and of being able to switch in or switch out the electric boiler at any moment, according to the requirements of the electric power supply authorities, means being able to utilize excess power at all times, to the great advantage of the power producer and of the power consumer, as well, this not only during industrial depressions but at other times, also.

Fig. 131 is an element of the Brown Boveri water-jet electric boiler which we give here in order to recall the principle on which this boiler is based. The electric resistance is formed of water jets which have a high resistance owing to their small section, a quality making the water-jet boiler suitable for high voltages. By suitable choice of the section, length and number of water jets the resistance offered by the jets can easily be made to suit any system voltage encountered. It is very important that there should be no spraying when the jets impinge on the electrodes, in order to prevent flash overs. The illustration shows how the electrodes are shaped — a patented Brown Boveri design — so that no spraying occurs. The high resistance of the water jets allows of operating with water containing much salt, i.e. with small blow-down volumes. There are no *ceramic parts* immersed in

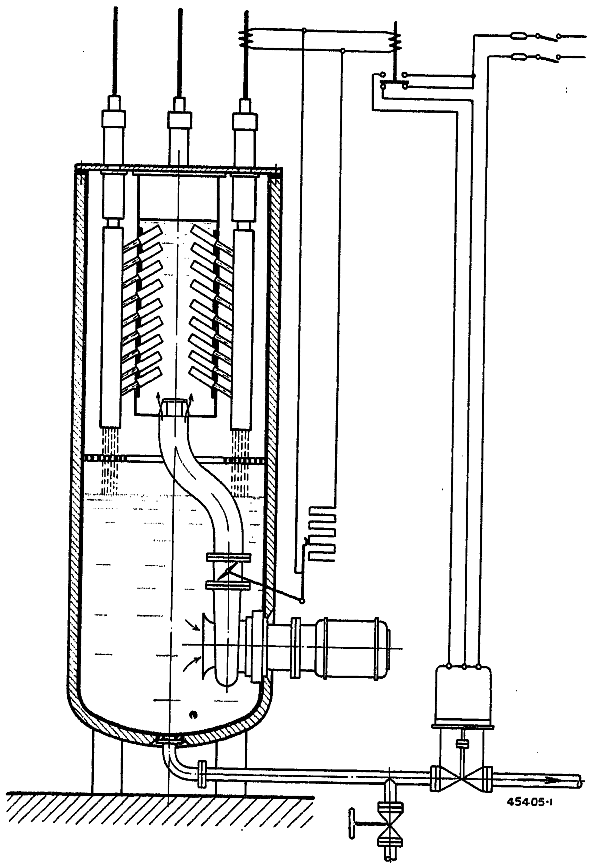


Fig. 133. — Automatic blow-down device for the electric boiler.
If the resistance of the water jets gets too low, that is to say if the throttle valve, for a given load be too far closed, then the blow-down valve is opened by a motor.

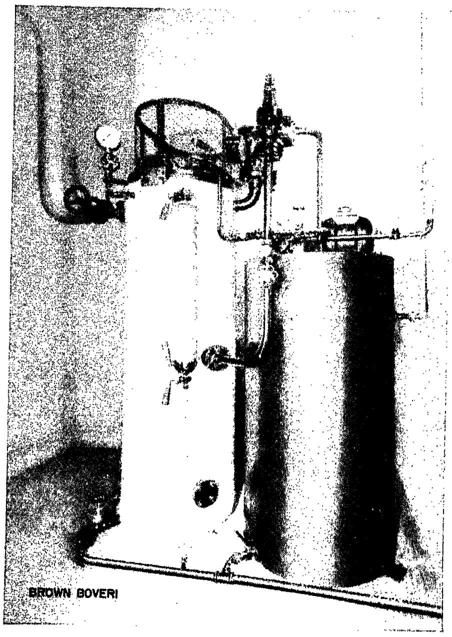


Fig. 134. — Low-voltage electric boiler for 100 kW, 380 V in the Latterie Luganesi, Lugano (Switzerland).
Feed-water tank beside boiler. Regulation is automatic, to a given pressure.

the water, in order to lengthen the track of the current, and this is one of the greatest advantages of the Brown Boveri boiler as it means greater service reliability and lower running costs. In all, the only ceramic parts are the bushing insulators. All those who have experienced the unending trouble of which ceramic elements built into the boiler are the seat, will not hesitate to choose the all-metal Brown Boveri boiler. Fig. 132 shows an electric water-jet boiler, 800 kW, 4000 V. The circulation pump with its motor, the pressure-regulating devices, the water-level regulating devices, which all work automatically, are shown in this illustration.

The principle of the automatic *blow-down regulator,* which we have developed in order to facilitate and improve the boiler service, is shown in Fig. 133. There is a given number of water jets for each load on the boiler, for a given salt concentration of the water and there is also a determined position of the butterfly-type load-regulating valve inserted on the pressure pipe from the circulation pump. When the salt concentration of the boiler water increases, the regulating valve must be further closed, and the number of water-jets diminished, the load remaining constant. There is a movable electric resistance combined with the regulating valve which determines the strength of an auxiliary current in function of the position of the valve, i. e. of the salt concentration. This auxiliary current is compared to the load current of the boiler and utilized to open the motor-driven blow-down valve. After the elapse of a blow-down time determined by a time relay, the blow-down valve is closed again while the water-level regulator allows fresh water to flow to the boiler. The process repeats itself until the salt concentration of the boiler water goes down sufficiently. This blow-down device in which the resistance of the boiler is used as a measuring resistance has the great advantage that the bushings, which being immersed are subject to wear, are not used as a measuring distance.

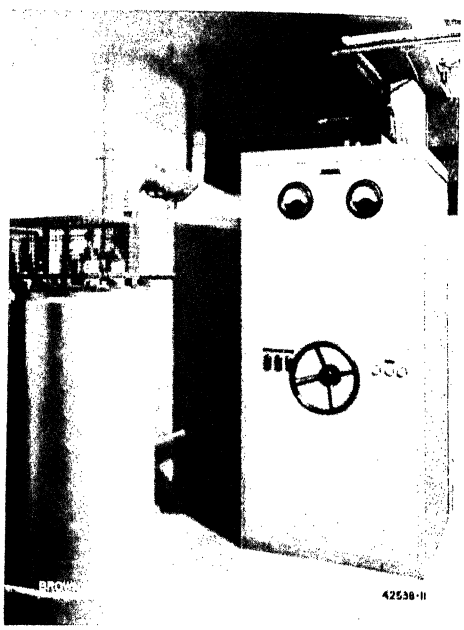


Fig. 135. — Low-voltage hot-water boiler, for 400 kW, 380 V in the Selve Works, Thoune (Switzerland).
The boiler adapts itself automatically to the heat requirements.

Last year, we also took up the building of *low-voltage steam and hot-water boilers* for voltages up to 500 V. In this case and contrary to high-voltage boiler design, we use immersed electrodes instead of water jets. No built-in ceramic parts are necessary, on account of the low voltages. The load is varied by altering the immersion of the electrodes, i. e. by lowering or raising the water level in the boiler. It will be clear, however, that this cannot be carried out at any speed. When load is thrown off with a return to a lower water level, the water of the boiler must evaporate or be allowed to flow off through an outlet valve, with a corresponding loss of heat; in the case of a central-heating boiler it must be driven into the expansion tank. As the requirement for steam increase, the boiler has to be filled up again by the feed pump. This is accompanied by the further difficulty that when a large quantity of cold water is injected into the boiler the conductivity of the boiler water and with it the passage of current falls for a determined electrode immersion, and also that much heat is required to heat up this new water. Thus, when the load rises, the evaporation begins by falling which may cause big pressure fluctuations in automatic service. We got over this difficulty, inherent to the principle of the boiler with immersed electrodes which is, in other respects, so suitable, by preheating the feed water in an accumulator lodged inside the boiler and by bringing it up to as near the evaporating temperature as is possible. This means that it is no longer necessary to furnish the heat required to warm

the feed water when the load goes up and a greater amount of steam is immediately generated. In order to shorten the time necessary to fill up the boiler, the feed pump is made considerably bigger than would be necessary for full-load feed-water supply. In ordinary service, the excess quantity of water is allowed to flow back through a spring-loaded overflow valve, from the pressure pipe of the feed pump into the feed-water tank. This measure insures very stable operation of the boiler and pressure fluctuations are reduced to a minimum. Fig. 134 shows a low-voltage electric boiler, 100 kW, 380 V, 6 kg/cm² abs in the

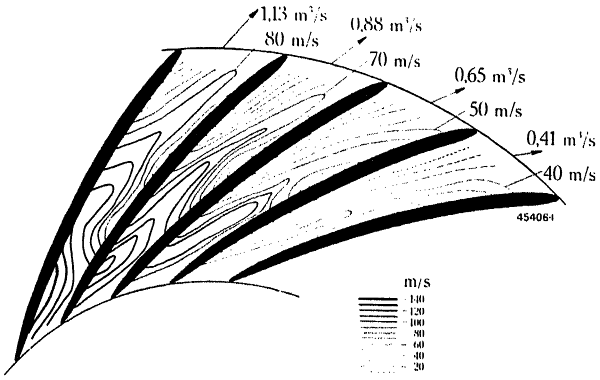


Fig. 136. — Curves of equal speed in the blade channels of a running blower disc at different outputs.

The very different speeds on the two sides of the blade are noticed at once, as well as the pressure jumps at the end of the blade.

Latterie Luganesi, Lugano (Switzerland) and running to the general satisfaction of the client.

The *low-pressure hot-water boilers* are, fundamentally, the same as the low-voltage steam boilers. The water is heated up in the boiler to the temperature corresponding to the head of water in the central heating system above the boiler. This water, at about 110—130 ° C, is mixed with the water in the central-heating circuit by means of a circulating pump. An automatically-controlled valve regulates the amount of water mixed according to requirements. If a boiler of this kind is added to a big heating plant, the improved water circulation improves the heat transmission to the radiators, an additional and welcome amelioration. Fig. 135 shows a low-voltage electric boiler for 400 kW, 380 V, in the central-heating system of the Selve works, Thoune (Switzerland).

F. COMPRESSORS AND BLOWERS.

Our development work on turbo-blowers, begun 30 years ago, has given new and encouraging results in recent months. When investigations were first started, there was, really, very little known of the processes of which the passages between the vanes of the rotor and the stationary passages were the seat. At first, these channels were adjusted purely empirically with the object of getting as good a flow as possible. Then, through tests, which required great pains and patience, we managed to collect pressure and flow-velocity measurements from the rotor. These measurements were made through the

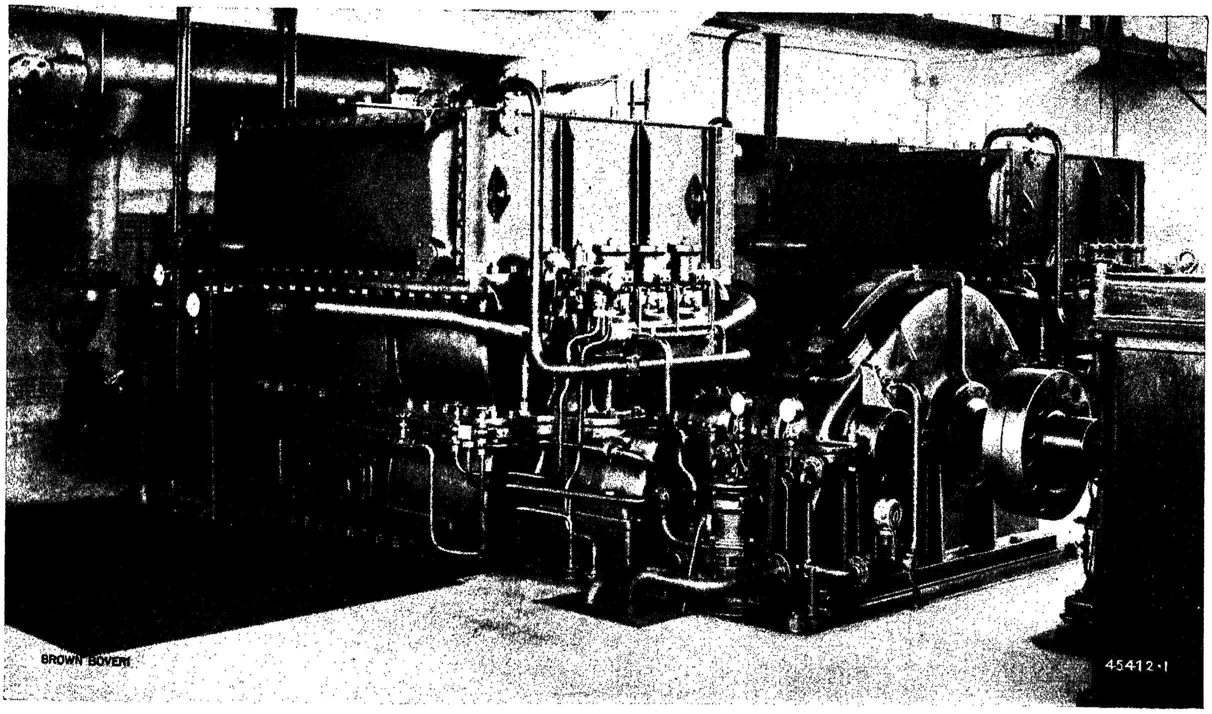


Fig. 137. — Charging-compressor sets for a charged absorption process in a nitric acid works.

The compressor compresses 330 m³ of ordinary air to 8·5 kg/cm² abs and requires 1780 kW for this. The hot gases come back from the process at 7·5 kg/cm² abs and 500° C and are able to produce 1400 kW in the gas turbine. The remaining 380 kW are furnished by a driving motor, which, however, is built for 1400 kW, so as to be able to act as a stand-by.

hollow shaft and they were the first practical investigations to give valuable data on the real flow process and power exchange in the channels formed by the rotor blading. Fig. 136 recalls these exceptional measurements, which allowed of improving the turbo-blower considerably and explained some incomprehensible phenomena inherent to this class of machine. The cause of the violent pressure fluctuations in the stationary passages was revealed, the same applies to the whining note given out by the early blowers and to the unexpected lack of stability in the air delivery. It was also made clear why the efficiency of pressure conversion was considerably lower than that of power generation. New flow measurements carried out on models showed what were the most advantageous shapes to give to the suction and pressure channels, to the diffusers and to the reversing passages, in order to keep losses as low as possible. As Fig. 143 shows, for example, these investigations, together with careful attention to every constructive detail, allowed of arriving at really good blower efficiencies.

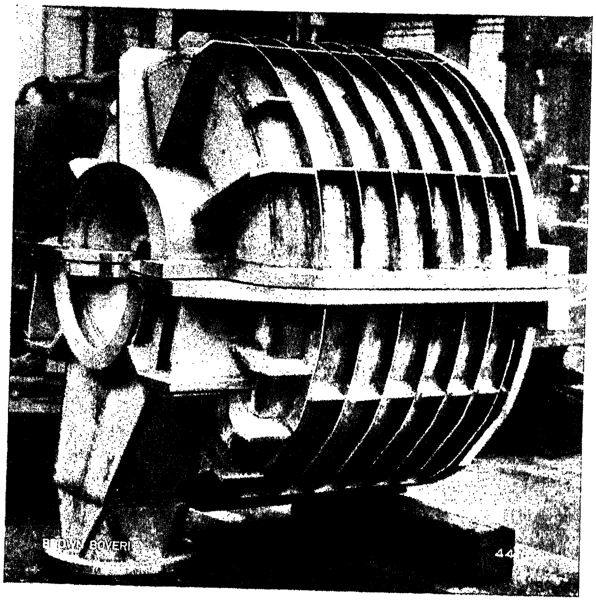


Fig. 138. — One of seven compressors for nitric-acid works to deliver 315 m³/min of nitrate gases at 7·4 kg/cm² abs.

The whole compressor with shaft and discs is made of rust-proof chrome-nickel steel. The gases come back from the process at 5 kg/cm² abs 100° C and flow through a gas turbine in the housing of the compressor, giving 360 kW back to the compressor shaft.

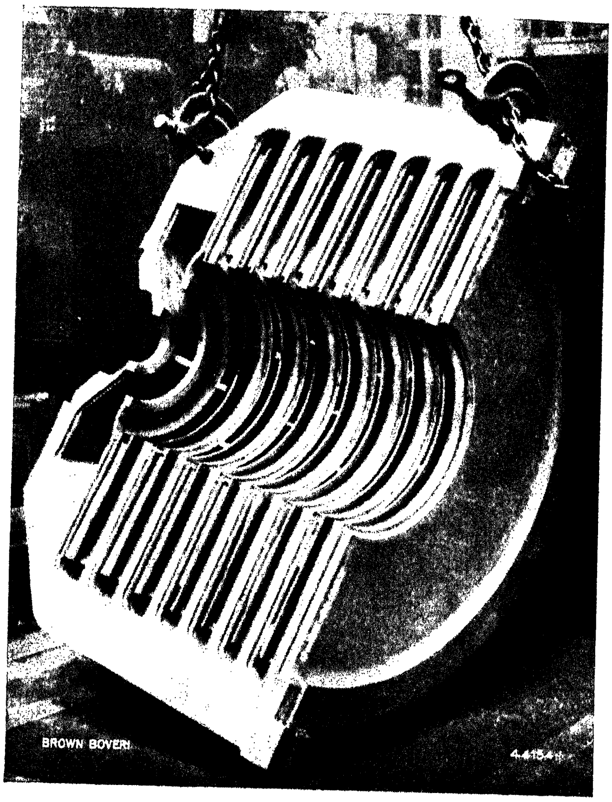


Fig. 139. — One of seven rust-proof chrome-nickel steel cylinders of welded construction to deliver nitrate gases.

The cylinder and water-cooled chambers are entirely built up of metal sheeting welded together.

These high efficiencies of our modern turbo-blowers when used in conjunction with gas turbines open up new fields of application in *charged chemical processes* and *charged combustion processes.*

In the first development stage, the Büchi charging process was difficult to carry out and could only be applied to big engines, because of the considerable losses in the charging set. The process has only been applied with entire success on a broad basis within the last few years, that is to say since the efficiencies of the charging machinery have been improved to such an extent that the power produced by the gas turbine sufficed not only for charging, but for scavenging and cooling the Diesel engine, as well.

In the case of the Velox steam generator, as well, combustion under pressure, which is an essential element of its working principle, is only a profitable process if the efficiencies of the gas turbine and charging blower are high. This is because the power input required for the charging blower is as much as 30 % of the steam power produced by the Velox and poor efficiency of the charging set means that far too much additional power is required to drive the set, thus bringing down the efficiency of the Velox itself as a steam generator. To-day, such strides have been made that the charging set does not only take very little additional power but, under certain conditions can, even, return power to the supply system.

1. *Charging compressors with exhaust-gas turbines in the chemical industry.*

In the chemical industry for the production of nitrogen and nitric acid, the absorption and also the adsorption process in the catalyst is often more advantageously carried out under high pressure and temperature that is to say as a charged process, the hot gases exhausted from the process being utilized in a gas turbine to drive the charging compressor. All the gas channels and reaction chambers are now much reduced in size, owing to the high pressure

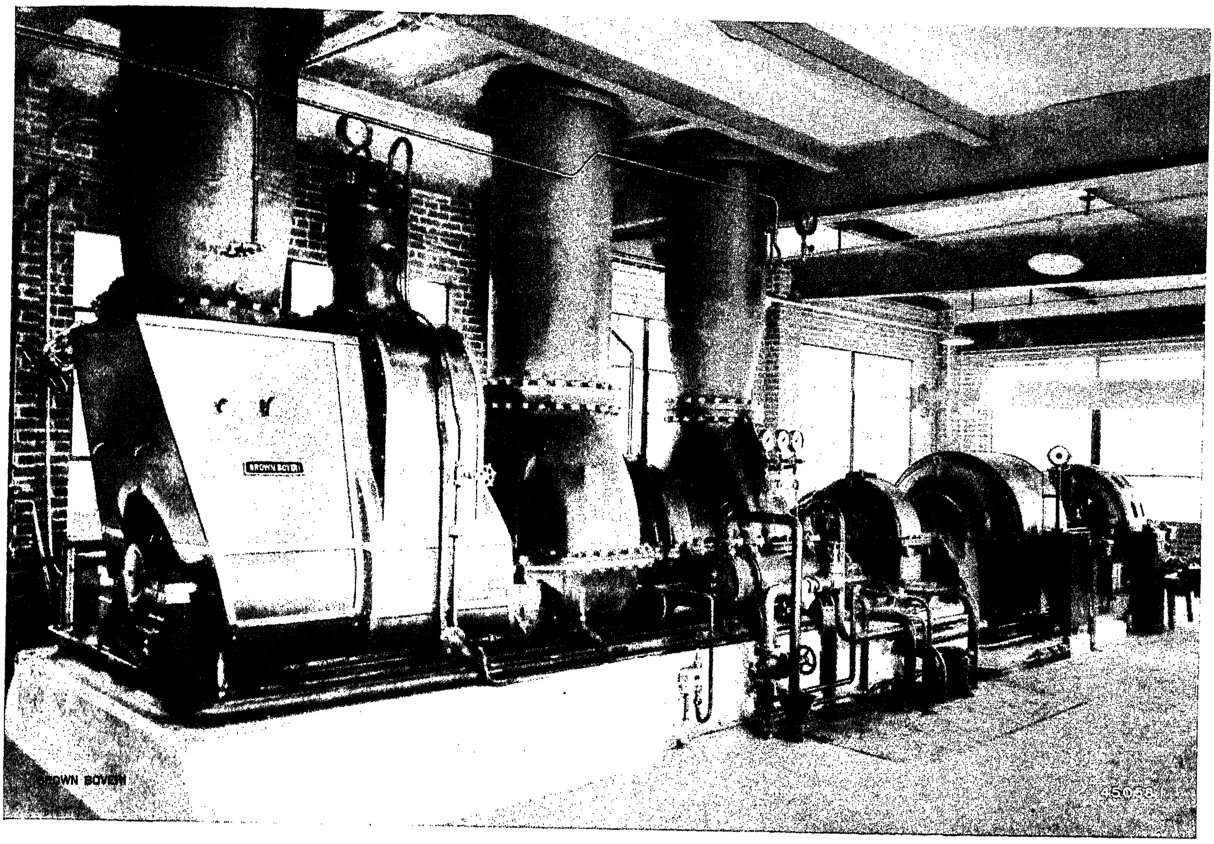


Fig. 140. — Big charging set composed of an axial blower, exhaust-gas turbine and generator, delivered to the Sun Oil Co., Philadelphia, U. S. A.

The blower compresses air and takes about 4400 kW. The hot gases restituted by the process produce about 5300 kW in the gas turbine, so that a generator delivering about 900 kW can be driven through a reduction gear, which restitutes this power to the electric supply system. The starting motor seen on the extreme right is for starting the set and bringing it up to about $^1/_5$ of the rated speed; there is also a starting combustion chamber in which the air is heated up by oil flame during the starting period and until the chemical process is fully going.

and high velocities, the absorption processes and heat transmissions in the heat transmitting apparatus take place advantageously and, despite the higher pressure used, big savings are effected, both in apparatus and buildings. Fig. 137 shows two charging compressors which compress 330 m^3 of air for an adsorption and absorption process, to 8·5 kg/cm^2 abs. The gases regained from the process, at 7·5 kg/cm^2 abs and 500^0 C are utilized in the built-on gas turbine and generate, therein, 1400 of a total of 1780 kW required to drive the compressor, the remainder being made up by a built-on electric motor, which has to provide the entire power required for compression, during the starting-up period.

Fig. 138 shows one of a set of seven compressors ordered from Brown Boveri for making nitric acid. The nitrate gases produced by adsorption of ammonia on the catalyst are compressed up to 7·4 kg/cm^2 abs. The hot residual gases drive an exhaust-gas turbine, lodged in the casing of the compressor and which restitutes 360 kW of power to the shaft of the compressor. Every part of the compressor (cylinder, shaft and wheels) is made of stainless chrome-nickel steel. The cylinder is cooled by external water jackets. This rather complicated body is entirely welded from chrome-nickel steel sheeting (Fig. 139), a fine testimony to our welding process and the skill of our welders.

Figs. 140 and 141 show an especially interesting charging set for a chemical works in America. This set not only takes care of the charging required for a certain process but returns a considerable amount of power to the electric system thanks to heat supplied to it, together with high turbine and blower efficiencies. This set comprises an axial compressor requir-

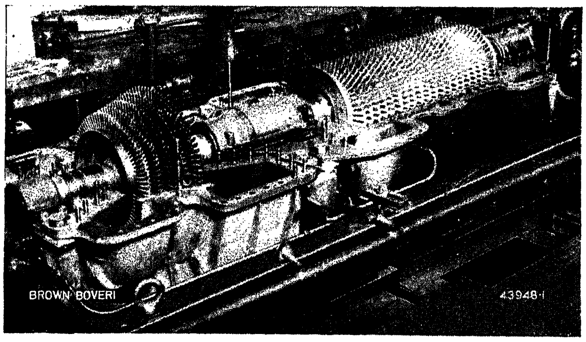


Fig. 141. — Charging set for a compressor output of 4400 kW, composed of an axial compressor, a gas turbine and a generator, which restitutes about 900 kW to the electric supply system.

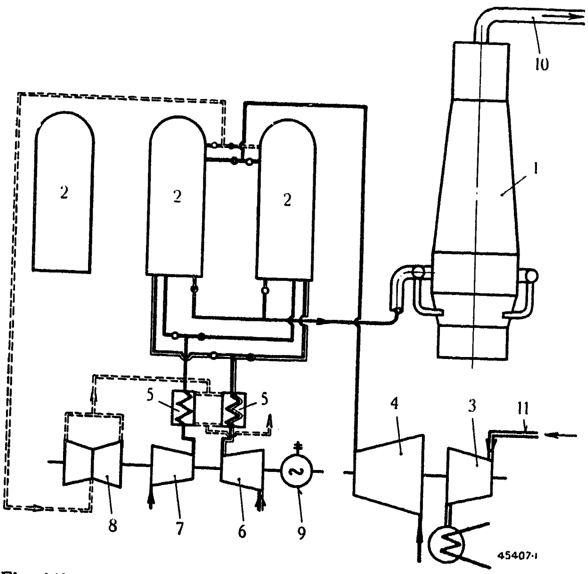


Fig. 142. — Diagram showing a Velox blast-furnace, air-blast plant with charged Cowper stove.

The Cowper stove is charged by blast-furnace gases at about 2·5 kg/cm² pressure and high velocity. This allows of making the Cowper stove smaller and it shortens the time required for charging it. Only two Cowper stoves are required (and a stand-by) for the process.

1. Blast furnace.
2. Cowper stove.
3. Steam turbine.
4. Blast-furnace blower.
5. Preheater for charging air and gas.
6. Charging blower.
7. Charging-air blower.
8. Exhaust-gas turbine.
9. Auxiliary motor.
10. Gas pipe to Velox steam generator.
11. Steam pipe from Velox steam generator.

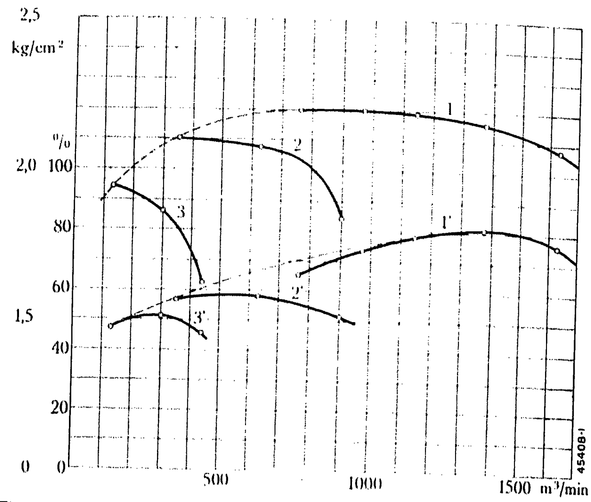


Fig. 143. — Pressure-volume curves 1 – 3 and efficiency curves 1' – 3' of a Brown Boveri turbo-type blast-furnace blower for 1500 m³, 2·1 kg/cm² abs, for different settings of the movable diffusers.

Delivery is stable and efficiency good, down to low loads.

ing about 4400 kW, a gas turbine, driven by the gases at 500° C restituted by the chemical process, and producing 5300 kW and a synchronous generator coupled through a reduction gear which returned the excess of 900 kW to the electric supply system.

The starting of this set and the apparatus for that purpose are also worthy of note. As long as the chemical process is not in full swing, the temperature of the gases returned is low and the same applies to the output of the gas turbine. An auxiliary starting motor is used, seen on the extreme left in Fig. 140, to bring the charging set up to a fraction of its rated speed, 20 %, for example. Under these conditions the compressor output is only about 1 % of its full-rated figure and the starting motor and the starting power called for are correspondingly small. To raise the speed further, the air delivered by the compressor is, first, forced through a branch pipe into an air-cooled *starting combustion chamber*, here it is heated up to 500 °C, by oil flame and then led to the gas turbine. As is known, the output of the latter increases with the absolute temperature of the driving gas, so that it, now, supplies more power so that, by keeping up the heating of the compressed air, the charging set is brought up to full speed, rapidly. The starting motor is coupled to the charging set by an overtaking coupling and it is, thus, caught up by the gas turbine and cut out after the starting

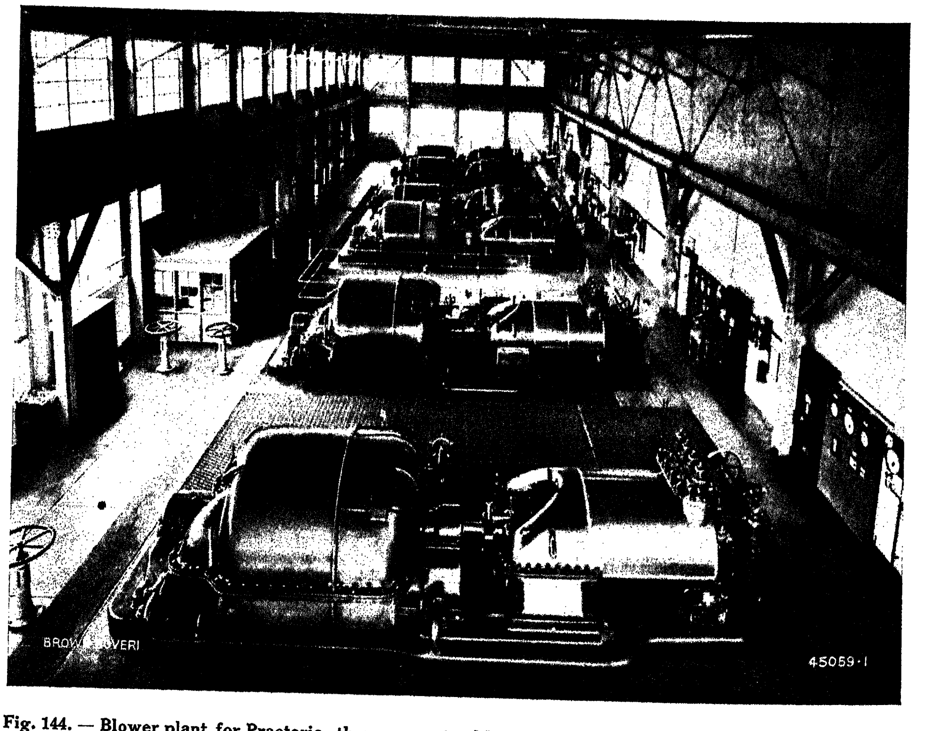


Fig. 144. — Blower plant for Praetoria, three converter blowers for 1500 m³, 0·88/2·15 kg/cm² abs, driven each by a synchronous motor of 2860 kW.

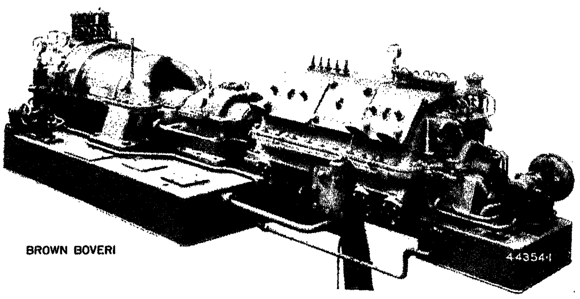


Fig. 145. — Turbo-compressor VW 509.
It can be utilized for as low outputs as 50 m³/min at 8 kg/cm² abs and it has thus entered a field which was, formerly, held by cell-type compressors and reciprocating compressors exclusively.

process is at an end. The starting combustion chamber is placed outside the machine chamber as a connection piece between the inlet and outlet gas ducts over the set. This starting process and some special devices are patented.

2. *Blowers for blast furnaces and steel works.*

The phenomena of enhanced heat transmission from a gas to the wall of the gas tube, under the effect of high-pressure and high gas velocity, made use of in Velox steam generators, has led to the suggestion being put forward that it would be advantageous to use a *charging process to heat the blast of a blast-furnace.* Fig. 142 shows a diagram of a charged blast-furnace plant. The cowper stove is heated up by blast-furnace gases at a pressure of about 2·5 kg/cm² abs at 800—900° C. Two charging blowers bring gas and air to the desired pressure; an exhaust-gas turbine utilizes the hot gases coming from the Cowper stove, and drives the charging compressor. As the Cowper has to be pressure proof, in any case, for the heating process no special cost is incurred by charging under pressure, which

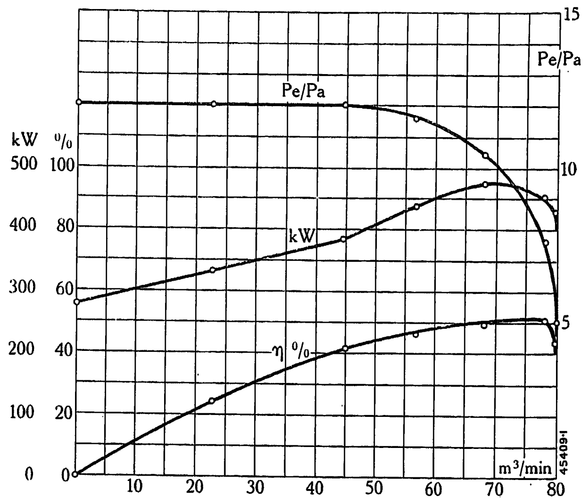


Fig. 146. — Test results taken on the smallest high-pressure turbo-compressor yet built.
Despite its small size, the efficiencies are so high that the turbo-compressor with steam-turbine drive is the most preferable solution, for low outputs as well, when the other advantages of the turbo-unit are taken into account.

also, makes it possible to use the Velox principle, i. e. to work with high speeds, reduced hot-gas sections and small heat transmission surfaces and, thus, to reduce the unwieldy dimensions of the modern Cowper. Of course, the pressure of the blast-furnace gases must be, somewhat, increased so that the higher resistances of the smaller Cowper can be overcome, at discharging. As charging and discharging of the cowper stove take place at about the same pressure, there is the further advantage that equal times are required for charging and discharging and that two instead of three Cowper stoves (as before) are required for operating a blast furnace.

Out of a considerable number of blower plants for steel works delivered, Fig. 144 shows the blower

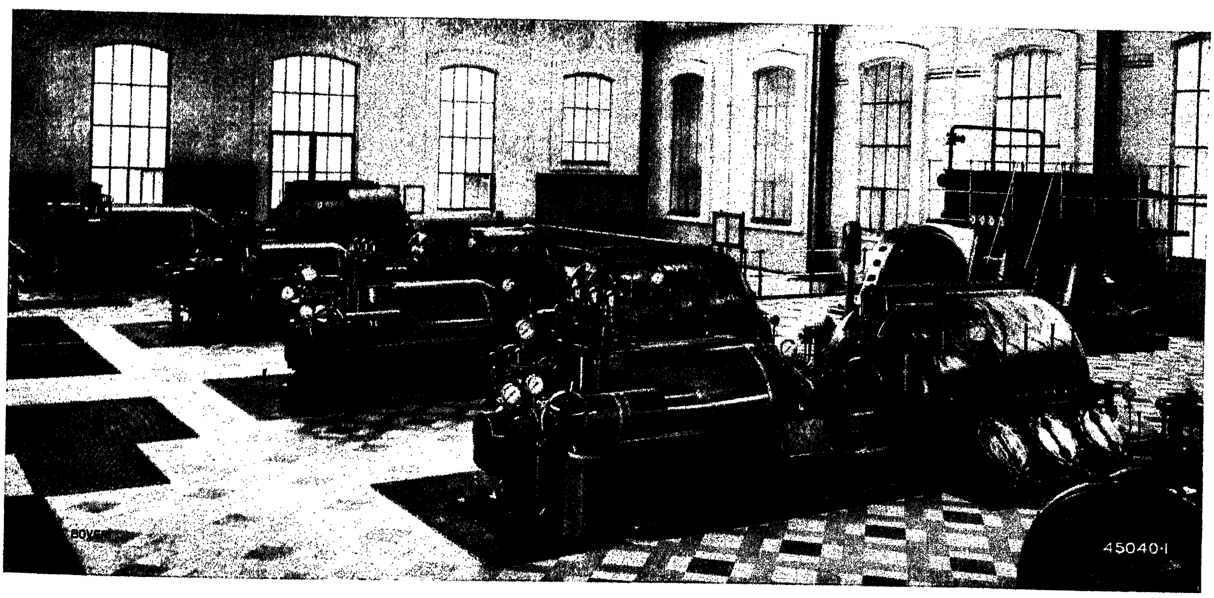


Fig. 147. — Compressed-air station of the Charbonnages de Beeringen (Belgium) with four turbo-compressors for 350 to 600 m³/min of air delivery and 8 kg/cm² abs pressure.

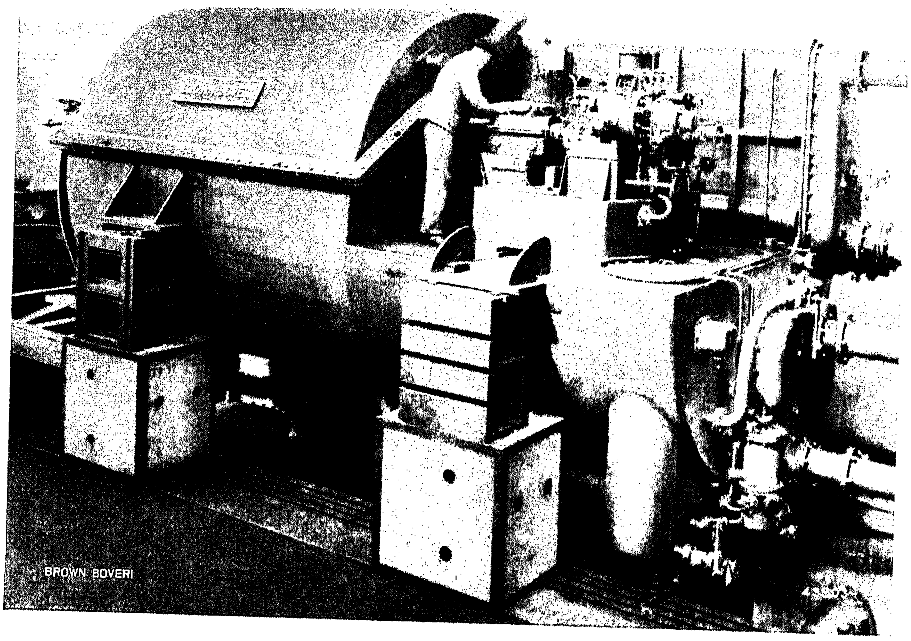


Fig. 148. — Steam-turbine driven Frigibloc for a Polish artificial-silk mill, to deliver 1,300,000 kcal/h at 13° C.

To prevent heat exchange, the turbine is outside the Bloc proper.

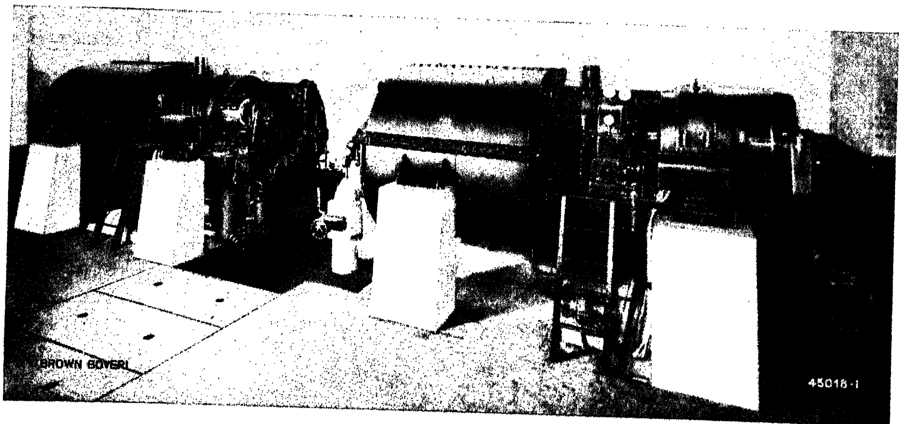


Fig. 149. — Two Frigiblocs each for 320,000 kcal/h belonging to the Brasserie Richard Frères Ivry sur Seine (France) driven by D. C. motors.

To facilitate brush supervision, the motor is outside the Bloc proper.

plant in Praetoria of the South African Iron Steel Industrial Corporation. Thanks to excellent results achieved with the first two 2860-kW blast-furnace blowers driven by steam turbines, a third unit was ordered and, later, a high-pressure turbo-compressor, which is shown in Fig. 145. Interesting measurement records taken from a big blast-furnace blower are given in Fig. 143. This unit is in the plant of the Lancaster Steel Corporation Ltd., in Irlam. The blower has the patented movable diffusor blading which allows of a range of air delivery down to no-load. At rated output, the efficiency attains 80 % and remains excellent over the whole range of output regulation by means of the movable blades, down to small loads.

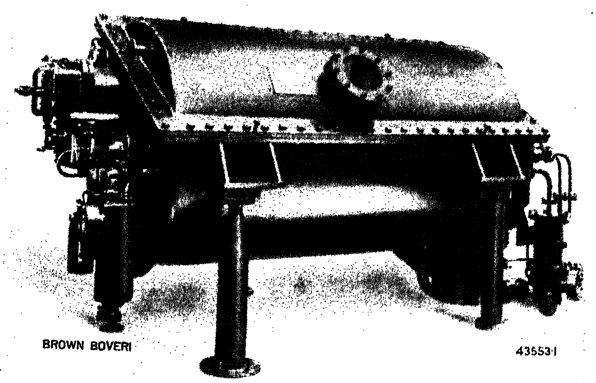


Fig. 150. — The smallest Frigibloc built up till to-day, for 50,000 kcal/h.

3. *Compressed-air generation.*

In the field of compressed-air generation for pneumatic tools and for outputs of less than 100 m^3/min, two-stage reciprocating compressors and Roots (cell-type) compressors have been used exclusively up till to-day, because, both in efficiency and price, they were more advantageous than the turbo-compressor. However, the advantages inherent to the turbo-machine and its driving steam turbine are so great, as far as running and upkeep are concerned, that there has long been a demand for a practical, small turbo-compressor. To-day, thanks to improvements introduced to both blading and housing it has been found possible to create a new turbo-compressor model with an output of 50—80 m^3/min of air at a pressure of 7—10 kg/cm² abs, the efficiency of which is only slightly below that of a cell-type compressor. Fig. 145 shows the new machine, which has nine compressor discs in a water-cooled housing and a central intermediate water cooler. Fig. 146 gives the measurement results attained. The efficiency of 50 % must be considered good, when the big pressure ratio

and small volume of air handled are taken into consideration. The range of regulation is a striking feature, the volume of air delivered being variable from overload down to zero by means of the regulated turbine.

The compressed-air central station of the Charbonnages de Beeringen is shown in Fig. 147. Owing to the excellent performance of Brown Boveri compressors, this station has been gradually built up until to-day, it contains four Brown Boveri turbo-compressors of 350 to 600 m^3/min of air and 8 kg/m^2 abs delivery pressure.

G. REFRIGERATION.

The output range of our Frigibloc has been increased by one biggest and one smallest model. Thanks to the little space it takes up, its simple and rapid erection and its great economy, the Frigibloc offers remarkable advantages in big refrigerating plants as compared to other refrigerating machines built up of different, independent elements. In small plants, chiefly in trades and on board ship, the fact that no supervision is called for together with the compact design makes the Frigibloc a most advantageous acquisition. When steam-turbine and D. C. motor-drive (Figs. 148 and 149) are used the drive is not inclosed in the Frigibloc itself, this in order to prevent heat exchange between the turbine and the Frigibloc, in the first case and in order to allow of commutator attendance, in the second case. The compressor shaft is, then brought out through a sealing gland in the housing independent of the machine and having oil sealing. The Bloc thus remains entirely gas-tight. Fig. 150 shows the smallest Frigibloc built, so far, for a refrigerating capacity of 50,000 calories, intended for breweries, small refrigerating plants, ships, etc.

H. AERODYNAMICS AND AEROPLANES.

Military aeroplanes are called on to fly at altitudes of 5—10,000 m and to plane down rapidly and unobstrusively; at no far distant date, commercial planes will certainly be required to fly at very high altitudes, as well, in order to increase travelling speed and bring down the time of intercontinental journeys. As at such altitudes the weight of air drawn in falls considerably (for example at 5000 m alt., it is only 50 % of that at sea level), Brown Boveri created a type of high-speed turbo-charging blower for aeroplanes, driven through a reduction gear from the aeroplane engine; this was used during the War. These charging blowers are driven, to-day, by the Büchi process, that is by a gas turbine fed from the engine exhaust, which is a great improvement on the former arrangement. The reduction gear is eliminated and the somewhat complicated coupling between the high-speed blower and the reciprocating engine with its cyclic irregularity is dispensed with; further no useful engine power is used for charging.

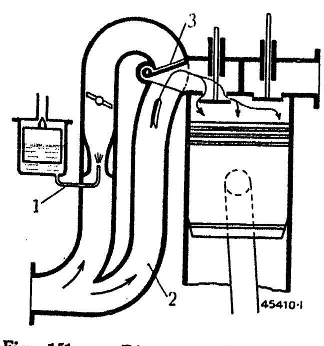


Fig. 151. — Diagram of charged petrol engine, with scavenging.

During the scavenging period, the scavenging air is led round the carburettor, in a by-pass pipe with two-way valve, this in order to avoid waste of fuel.

Charging of petrol-fed aeroplane engines can be carried out with or without cylinder-chamber scavenging. When *scavenging* is applied, the valves, cylinder chamber and gas-turbine blade wheel are efficaciously cooled and the remainder of the burnt gases is driven out; the output of the engine, for a given charging pressure, can be increased above that of the charged but unscavenged engine. To carry out scavenging, however, the air drawn in must be carried round the carburettor according to a patented Brown Boveri process (Fig. 151 shows the method, diagrammatically), during the scavenging process in order to prevent unnecessary waste of petrol. There is a by-pass 2, parallel to the carburettor 1. Valve 3 switches the carburettor out of the air-suction branch during the scavenging process and allows the air drawn in to flow straight to the engine through the by-pass. This change-over device is not required when *petrol injection engines* are used, for which there would appear to be a future in aviation; in this case the charging process is the same as with the Brown Boveri-Büchi charged Diesel engine.

In ordinary unscavenged petrol engines the temperature of the exhaust gases is about 800°, so that special cooling measures must be taken to protect the blades and disc of the gas turbine. The exhaust gases are led from the different sets of cylinders, as in the case of Diesel charging, to two or to three separate sets of nozzles of the gas turbine. There are cooling nozzles inserted between the exhaust-gas nozzles, through which cold air flows to the gas

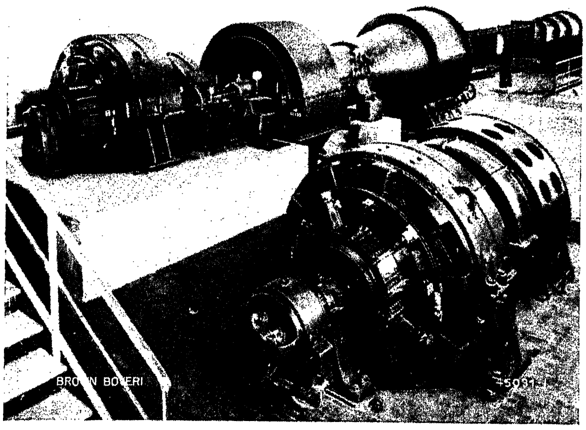


Fig. 152. — View of the super-sound velocity wind tunnel of an aerodynamic institute.

Models of aeroplane types, projectiles, etc. can be tested in this tunnel; up to speeds of 2300 km/h. A multi-stage axial compressor driven by a 1000-kW D.C. motor drives the air through a circuit.

turbine and cools its housing, blades and disc while avoiding the engine in its course. By using high speeds (r. p. m.) for the blower and turbine disc and by using high-temperature proof material as well as by careful design, it has been found possible to bring down the weight of the charging set for aeroplane engines to about one tenth of that of the usual weight of a charging set for a stationary engine.

It is obviously desirable to test out the effects on the engine of flight at high altitudes first on the test bed before doing so in trial flights. To this end, our firm builds so-termed *altitude-test stands* in which aeroplane engines are fed with combustion air at the pressures and temperatures met with at high altitudes, as, for example, 0·25 kg/cm² abs and — 50° C, and in which a flow of high-altitude air over the engine itself can be reproduced, if desired.

In this field of development, we would recall that our firm also builds *wind tunnels for aerodynamic investigations at super-sound and sub-sound velocities.* Fig. 152 shows a super-sound measurement wind tunnel built, according to Prof. Ackeret's suggestions, by Brown, Boveri & Co., Ltd., Baden and Tecnomasio Italiano Brown Boveri, Milan. Aeroplane parts, projectiles, etc. can be tested in this tunnel under wind velocities up to 2300 km/h. The air is driven through a circuit by a multi-stage axial blower, the tunnel being under a pressure of only 0·20 kg/cm² abs in order to reduce the driving power necessary for the compressor. A variable-speed D. C. motor of 1000 kW drives the blower, the said motor being supplied from a converter set, seen in the illustration.

IV. TRACTION.

A. ELECTRIC LOCOMOTIVES AND COACHES.

We mentioned, in last year's report, the efforts made by various railway managements to render their respective traffic systems, based on conceptions which were becoming somewhat obsolete, both speedier and more flexible, by the introduction of light fast-running motor coaches or motor-coach trains and to win back, in this way, part, at least, of the passenger traffic lost to road competitors. This brought the *motor coach* to the fore, while tending to relegate the heavy locomotive to the background, an evolution which has been marked by the lively interest recently manifested for electric motor coaches on systems which were already electrified and for Diesel-electric motor coaches on the non-electrified lines.

At the beginning of last year, the *Swiss Federal Railways*[1] gave an order to Swiss electro-mechanical manufacturing plants for the electrical equipment of two three-coach trains, of the light-weight high-speed type.

[1] According to the second programme of electrification of the Swiss Federal Railways, the Gossau-Sulgen (22·432 km) and the Giubiasco-Locarno (17·662 km) line sections were electrified. This brings the total of full-gauge line kilometers electrified up to 2,098·571 at the end of 1936, out of a total of 2868 km.

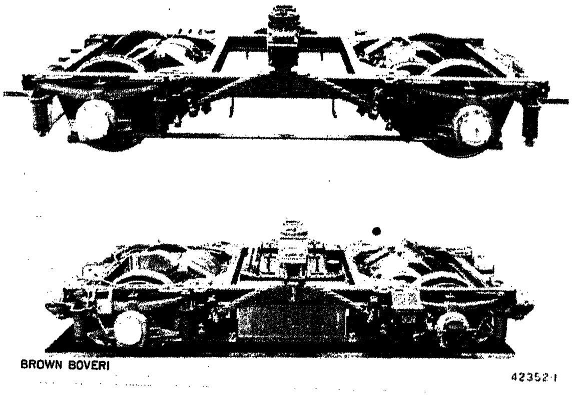


Fig. 153. — Bogie for double-unit and triple-unit motor coach.
Upper illustration:— Bogie with built-in motors.
Lower illustration:— Bogie with built-in motors and transformer.

The German State Railway Company ordered from Brown, Boveri & Cie. A.-G., Mannheim similar three-unit A. C. motor coaches for 120 km/h maximum speed, this to complete an earlier order for double unit motor coaches which had given general satisfaction. The delivery comprises 13 three-coach unit trains each made up of three closely-coupled coaches. The connections are such that both end coaches can be driven without middle unit or else the two end coaches with two coaches between them. Further, as many as three such trains can run together in multiple-unit control connection. Each coach unit has a driving bogie and runner bogie. The continuous output rating of a three-unit motor train is 6 × 305 H. P. at 84 km/h. The motors are nose-suspended, of standard type. As in the case of the double motor coaches already delivered, the transformers are suspended to the coach body, below, and project down into the driving bogies (Fig. 153). The total weight of a three-unit-train is 144 t, there being 188 seats, which gives a specific tare of 770 kg per seat.

Tecnomasio Italiano Brown Boveri, Milan got an order from *S. A. Ferrovia Nord, Milan* for the electric equipment of three four-axle motor coaches (3000 V D.C.). The 12 former motor coaches of this railway, for which our concessionaries delivered the electric equipments, had nose-suspended motors while the new ones have motors rigidly secured in the frames of the bogies. Drive is from the motors to a gear wheel running on a stationary quill-shaft length. The springs forming the flexible connection to the driving wheel are built directly into the said gear wheel. This is yet another application of our spring-coupling drive design, mentioned in the last report, and which has given such satisfactory results on the R_e 2/4 201—207 light motor coaches of the Swiss Federal Railways. Our design of drive

with rigidly secured motors and rotating quill-shaft and spring couplings were given a trial on two driving axles of the double motor coach built by other makers on the Rotterdam-Hoek van Holland line of the Dutch Railways; these coaches were put into service in 1935.

The Czechoslovakian Brown Boveri Werke got an order from the *Czechoslovakian State Railways* (C. S. D.) for the electric equipment of two Diesel-electric motor coaches having, per bogie, a Diesel engine with main generator with mixed self and separate excitation, of 132 kW, 1320 r. p. m., 250 V and a nose-suspended driving motor for 120 kW one-hour rating at 800 r. p. m. The Brown Boveri output-relay control is used on these coaches.

The electric equipment of a *Diesel-electric trolley-wire inspection coach* should be mentioned, here. The *Austrian Federal Railways* ordered it from Brown Boveri-Werke, Vienna. This is a two-axle unit with a repair and inspection platform which can be raised and swung round. It has compressed-air and hand braking, two driver's cabs and a measuring bow. The electrical equipment comprises a counter-compounded generator driven by a Diesel engine, 107 H. P. at 1600 r. p. m., a nose-suspended motor, 58 kW, and the requisite control gear.

In the field of *electric* and *Diesel-electric locomotives* the most important order is that of light express locomotives placed by the *Cie du Chemin de fer Paris-Orléans* (P.-O.-Midi) with our French concessionaries, the Cie Electro-Mécanique and with the Cie Fives Lille. Fundamentally, the design is the same as that of the Type 2 D_o 2 express locomotive for 1500 V D. C. and about 4000 H. P., 120 km/h (140 km/h) max. running speed delivered in 1925, on which occasion two units were built for testing purposes. The same driving motors are used in the new locomotives and the same drives (Brown Boveri individual axle drive) on both sides and located outside, combined with inner frame, and the same bogie design. Electrical and mechanical details, only, have been changed in the subsequent units ordered since the first two. Thus, the 8 new units, Nos. E 538—545, have no regenerative braking as they are not intended for mountainous line sections.

The mechanical part of the 8 new locomotives is built by the Cie de Fives Lille in their shops in Fives. The Cie Fives Lille also build the motors of three locomotives in their Givors shops, according to drawings by the Cie Electro-Mécanique. All individual axle drives are built in the Bourget shops of the latter company and the rest of the electric equipment in their Le Havre shops, as well.

The total number of express locomotives which the P.-O.-Midi and the Chemin de fer de l'Etat have ordered from the Cie Electro-Mécanique has now reached 68, including the units at present building; these are all of the same type and represent a total weight of about 9000 t.

Brown, Boveri & Cie. A.-G., Mannheim got an order for the transformation of a two-axle locomotive, built in 1906 for single-phase A. C. current, 5000 V, $16^2/_3$ cycles. This unit may be said to present an almost historical interest as regards the development of single-phase traction. It is of axle sequence B_o and is driven by two 147-kW one-hour rating, nose-suspended motors. Our concessionaries have to deliver the reduction gear drive with protective casing, the transformer, a hand-operated cam switch and the balancing choke coil.

A locomotive of the B_o-B_o axle sequence for 20,000 V contact-wire voltage, 50 cycles was put into service, last year, successfully. The single-phase current is transformed to D. C. in a mutator and supplied as such to the driving motors, the terminal voltage of which is controlled from the high-voltage side of the transformer supplying the mutator. After the two 1 B_o 1 B_o 1 + 1 B_o 1 B_o 1 locomotives No. 11,801 and No. 11,851 of the Swiss Federal Railways this is the third and successful application of our new high-voltage control.

We, also, got an order for the electric equipment of three big Diesel-electric locomotives, this year. One is a big 2 D_o 1 + 1 D_o 2 unit of about 220 t total weight for the *Rumanian Railways,* for which Messrs. Sulzer Bros., Winterthur (Switzerland) are general contractors. The equipment includes two Diesel sets of each 1900 H. P. continuous and 2200 H. P. one-hour rating with Brown Boveri-Buchi charging and eight driving motors with individual axle drive and the electric equipment and the complete control apparatus (servo field-regulator control).

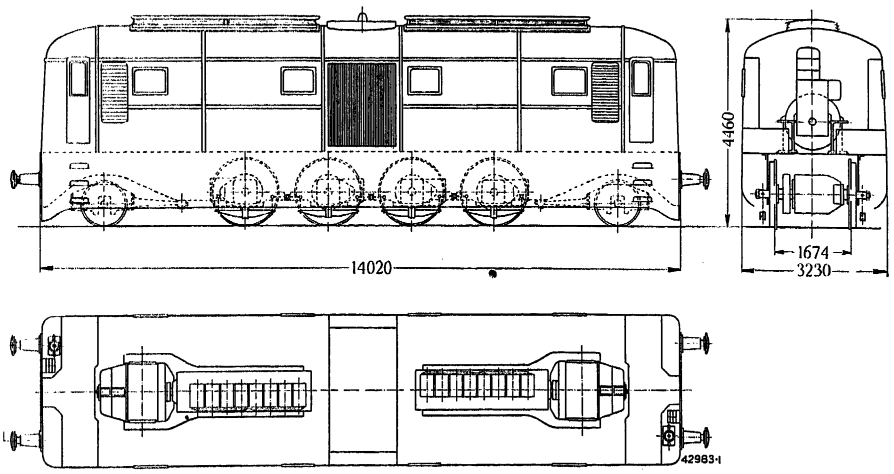


Fig. 154. — Diesel-electric locomotive of 1 D_o 1 axle sequence, 900/1000 H. P. of the Buenos Aires Great Southern Railways.

The locomotive develops a one-hour tractive effort of 24,000 kg at 35 km/h and a max. running speed of 100 km/h. It is intended for the Campina-Brasov (gradient up to about 2·8 %) line section and must haul 600-t trains. Both halves of the locomotive are identical, but one half cannot work alone. This locomotive is one of the most powerful and biggest Diesel-electric units ever built.

Two other wide-gauge Diesel-electric locomotives for which Messrs. Harland & Wolff Ltd., Belfast, are general contractors, are being built for the *Buenos Aires Great Southern Railway*. They are of the 1 D_o 1 type with a total weight per unit of 94 t. The max. running speed is 112 km/h and the one-hour tractive effort developed at 27·2 km/h is 7050 kg. Fig. 154 gives a type illustration of the locomotive, which has two eight-cylinder two-stroke Diesel engines each of 450 B. H. P., continuous rating. Our servo field-regulator control and multiple unit control is provided for. Our material per locomotive will consist of:— two generator sets each composed of one main and one auxiliary generator, the control equipment, instruments, safety devices and small material.

Further, *Messrs. Allis Chalmers Mfg. Co., Milwaukee,* got an order for the electrical equipment of a four-axle, Diesel-electric shunting locomotive type B_o-B_o driven by nose-suspended motors. The machine weighs 96 t and develops a tractive effort of 19,200 kg at 6·3 km/h. Brown Boveri servo field-regulator control is fitted.

Intensive work has been done, during 1936, on the further development of traction material (motors and apparatus for tramways and full-gauge lines). The tendency to increase the running speed, particularly of electrically-driven trains led to modifying the design of the *current collector* and the creation of a type which offered less air resistance at high speeds. As a result of our efforts in this field, we booked an order for 230 of the new pantograph current collectors which combine all the fundamental advantages of our older design with several new features. These collectors are intended for the new 90 two and three-unit trains of the Dutch State Railways which generally place their order with Dutch firms. The equipments in question will be used on the Arnhem-Utrecht-Gouda-Rotterdam, Gouda-Haag and the Amsterdam-Utrecht-Eindhoven line sections. These pantograph current collectors have carbon contact pieces which assure perfect current collecting of 1000 A at 60 km/h and also of 350 A at a speed of 150 km/h (Fig. 155).

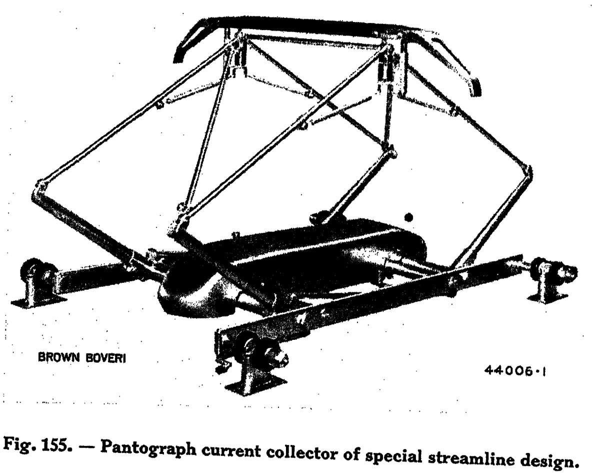


Fig. 155. — Pantograph current collector of special streamline design.

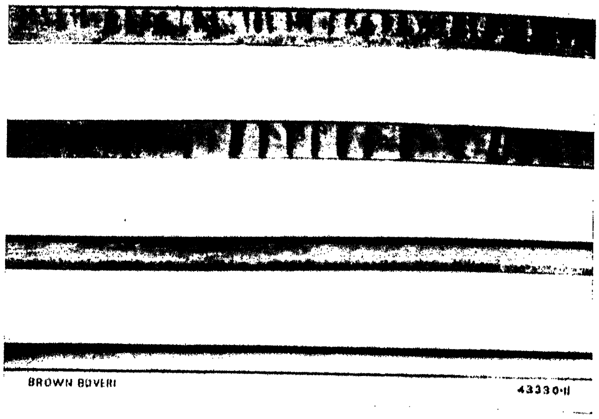


Fig. 156. Four lengths of contact wire from the Basle tramway system.

First and second illustrations from above: two wire lengths which were, originally, of 85 mm² belonging to the road passage underground of the Baden Station-Hirzbrunnen, built in on 3rd Sept., 1930 and changed on 19th July, 1935.

Fig. 156 shows the influence of *carbon contact pieces* fitted to the current collectors as regards the contact wire that is to say on the surface of the wire on which the collector piece slides and, therewith, the reduction of the *sparking* which is so *troublesome for neighbouring radio sets.* This figure shows different lengths of contact line taken from the Town of Basle system at different times. The first and second illustration, above, show two lengths of contact conductor with an original section of 85 mm² taken from the Basel DR-Hirzbrunnen road-passage under railway station, put up on Sept. 3rd, 1930 and replaced on July 19th, 1935. With service using "Lyra" type current collectors with U-shaped aluminium contact pieces, there were very marked grooves formed in the said contact wire, these were considerably smoothed out by the utilization of Brown Boveri pantographs with elevated contact piece supports having aluminium contact pieces during the last three months before the contact wire was changed. The third illustration shows a piece of contact wire of 70 mm² section taken from the Blumenrain-St. Johann suburban line section, put up

on March 19th, 1928 and changed on July 26th, 1935. There were no grooves formed on this wire with standard contact-wire height. At the beginning of the last service period of about three months duration with Brown Boveri pantograph current collectors, the wire had a rough surface which was transformed, after the three months in question, into a smooth surface, but not into a polished one. The fourth illustration shows a length of contact wire of 50 mm^2 section taken from the Güterstrasse line and replaced on Sept. 26th, 1935 that is to say fifteen days after all pantographs had been equipped with carbon contact pieces. The wire which had been smoothed by the use of Brown Boveri aluminium contact pieces during some months (see third illustration) became highly polished in only 15-days service with carbon contact pieces.

The general tendency to increase the travelling speed of full-gauge trains is also felt in tramway service as well. This can be attained either by an increase in the maximum running speed or else by increasing the acceleration at starting and retardation at braking. The conditions thus created make the nose-suspended traction motor a less desirable type than heretofore, as has been explained elsewhere. In order to attain for the vehicles in question the advantages of quiet running and little wear, we have developed a new cardan drive. The motor is rigidly suspended in the main frame or in the bogie frame and drives the pinion of a reduction gear through a cardan joint coupling. The big gear wheel of the said reduction gear is on the driving axle. The reduction gear is lodged in a casing carried, on one side, on the axle and, on the other, on the bogie frame. The well-known Hardy discs are used advantageously as Cardan couplings for all outputs met with in standard practice. Big reduction ratios of the gear are desirable as they allow of using small high-speed traction motors. The desired result is attained by milling the pinion of the reduction gear out of the shaft itself. This kind of drive has met with much success. After a year's trial with one of them, the Milan Tramways ordered 110 such drives for 60 coaches, from Tecnomasio Italiano Brown Boveri, Milan. These drives have, each, an output of 26·5 kW at 27 km/h and, including the motor, they only weigh, each, 350 kg.

If the output of the motor is so big that its length exceeds the available space which must remain for the Cardan shaft, the design can be so modified that the motor armature is mounted on a quill through which the cardan shaft is passed, with sufficient play for unavoidable relative movements. The cardan shaft and the quill are coupled together at the end of the motor opposite that of the reduction gear. Last year, an equipment of this type was delivered to the Bologna Tramways. Drive and motor weigh 450 kg, the output being 40 kW at a speed of 23 km/h.

During last year, the *Rigibahn Gesellschaft A.-G.*, Lucerne, decided to electrify the Rigi line section which begins at Vitznau (440 m above sea level) and leads to Rigi Kulm (1751 m above sea level). This is Europe's oldest mountain railway, which was opened as far as Staffel on May 21st, 1871 and, as far as Rigi-Kulm, on June 27th, 1873 (total length of line 6857 km, steepest gradient 25 %). The Riggenbach rack system was used here for the first time. Electrification should bring down running charges and speed up service. D. C. at 1500 V has been chosen. As first stage, three rack coaches (Fig. 157) each of 16-t tare have been ordered, to carry 80 passengers and to push a passenger coach of 6·3 t tare holding 60 passengers. The Swiss Locomotive and Machine Works, Winterthur are delivering the mechanical parts of these coaches and the electrical equipment is composed of two motors of 165 kW one-hour rating, allowing of attaining a speed of 14·6 km/h on the up-gradient. The max. running speed on the up-gradient is 18 km/h while, on the down-gradient, on the steepest gradient it is 12 km/h. On the down-gradient the motors work with lowered

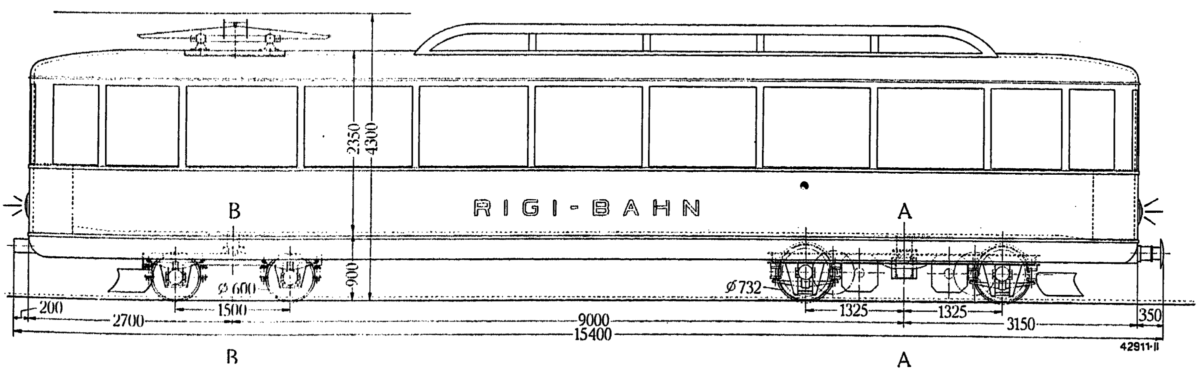


Fig. 157. — Drawing for one of the new geared motor coaches of the Rigi Railway.

A. Driving bogie. B. Runner bogie.

pantograph as auto-exciting generators, delivering current to resistances. We are delivering the entire electric equipment of all three coaches including traction motors, starting and braking controllers with 15 starting and braking steps, the starting and braking resistances, the electric signalling devices of six push coaches and the electric heating equipment. The basic traffic load should be covered by the three new coaches and the existing steam locomotives are retained, for the time being, for peak traffic requirements.

The *electric air-heating* system developed by us with all the improvements we have introduced has met with great success. We delivered electric apparatus for air heating for eight coaches for international service to the Dutch State Railways and the latter placed a repeat order for 12 more of these equipments, in August of last year. Per coach, there is a voltage change-over switch, various contactors, relays, series resistances as well as two heating couplings per coach of our standard design but having mechanical interlock which only allows of changing the couplings by using an interlocking key kept in the locomotive. In accordance with the heating voltages used internationally of 3000 or 1500 V, 1000 V and 50 cycles the voltage change-over switches have four service positions. The change-over of the switches in question is carried out by hand, on these coaches.

The air-heating systems delivered to the *Swiss Federal Railways* have been increased by the following equipments:— A steam heating element has been built into four passenger coaches for international service, apart from the electric heating for 3000 and 1500 V D. C. and for 1000 V single-phase A. C. at $16^2/_3$ and 50 cycles.

When the train is hauled by steam locomotive, the air is driven over the steam-heating element and over the heating resistances which, of course, are not under current. In the coach itself there are only the sheet metal ducts for the distribution of air and these are used both for steam or for electric heating. Thus, a number of valves which are in danger of getting frozen up with the ordinary steam-pipe systems are eliminated. Further, the weight of the steam-heating equipment is lower than with the ordinary direct steam-heating systems.

Up till now, it was considered sufficient to cut off the flow of hot air to the respective compartments by using a hand-operated air valve. Rotary magnets have now been fitted for operating the valves and these are governed by the thermostats of the individual compartments. The fact that the steam elements generate a lower temperature than those of the electrical elements means that a much greater amount of air is needed. The greater volume of air is advantageous for summer ventilation. A ten-fold exchange of air per hour is attained, a considerable improvement on the former five-fold renewal of air. As running speeds increase, the question of artificial ventilation is becoming more and more imperative as the opening of windows is getting intolerable. A solution entailing the use of ceiling ventilators holds out promise of satisfactory results.

This has been done, for example, in the case of seven light trailer coaches on the Swiss Federal Railways, which have electric air heating and a ventilator equipment. In the coaches in question not only are electro-magnetically controlled air-valves on the air ducts used but similar valves are built into the armature of the ceiling ventilators.

We have tried out our air-heating system on a new motor coach on the Basle Tramway system with successful results. The coach heats up quicker than with ordinary heaters, partly because there is a bigger amount of heating power used in air heating and, partly, because the coach fills rapidly with hot air, before partitions, floor, ceiling and seats have reached the temperature of the hot air. The built-in thermostat regulates the temperature in the coach to 12—13° C. There is better distribution of heat with air heating. Although the Basle Tramways made efforts to get better heat distribution, in coaches with ordinary heating system, by dividing up the radiators, the results were only partly successful. There are always localized hot areas under the seats below which the radiators are placed.

Air heating offers the advantage of improvement of cleaning facilities. There are no radiators under the seats. Upkeep should be easier and cheaper than with the ordinary heating system.

Finally, we would say that the Swiss Federal Railways have placed an order with us for the train preheating plant for Neuchâtel Railway Station; to replace the expensive and troublesome system now in use of heating up trains in advance by means of electric locomotives.

Twenty *train-lighting generators* for a one-hour output of 3150 watts, 105 A, 24—30 V, 370—2000 r. p. m. were built, for the first time, to a nose-suspended motor design for the Dutch State Railways. These generators have armature roller bearings and axle roller bearings. This equipment opens up an interesting prospect as the higher running speeds coming into favour and certain climatic conditions make belt drive more and more unsuitable.

B. VELOX LOCOMOTIVES.

Fig. 158 shows the projected layout of a Velox express train locomotive 5500 H. P. for 180 km/h

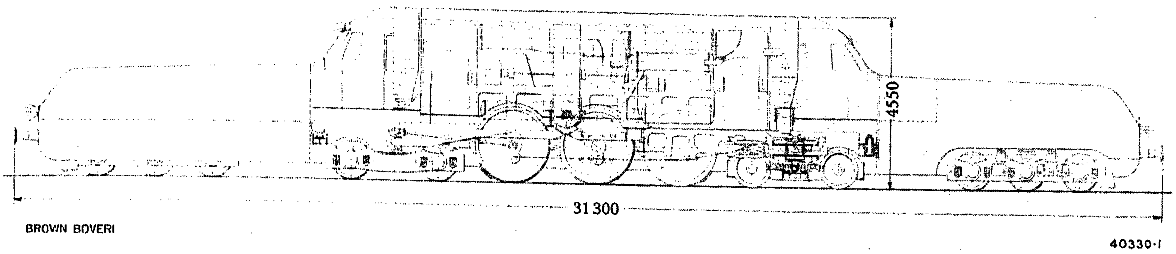


Fig. 158. — Project of a 5500-H. P. Velox-locomotive, for 180 km/h running speed.
There are two Velox units on the locomotive, each for 20 t/h of steam at 60 kg/cm² abs and 400° C. The Velox steam generator allows of lodging any power desired on a locomotive.

travelling speed. The tare with 10 t of oil and 60 t of water is 230 t. It has two independent Velox units each for 20 t/h of steam, 60 kg/cm^2 abs, 400^0 C. The wheels are driven, independently, by high-speed steam engines of high efficiency. The working out of this project showed once again, that there is no difficulty to be encountered in getting any output desired from the locomotive with Velox steam generators. The high efficiency of the Velox steam generator and of the machinery plant is especially advantageous on a locomotive on account of the lowering of running charges, lightening of the weight of the locomotive and increase in the radius of action.

C. DIESEL-MECHANICAL VEHICLES.

Fig. 159 shows the frame of a Diesel engine coach of the German State Railways, driven by a high-speed Maybach four-stroke engine. The Brown Boveri charging set seen in the centre, above, brings up the output of the said engine considerably.

Fig. 160 shows a truck engine by Ad. Saurer A.-G., Arbon (Switzerland). The small charging set seen on the right increases its output from 150 to 225 H. P. Fig. 161 shows a locomotive engine of the American Locomotive Co., Auburn, the output of which has been raised from 600 to 900 H. P. by the built-on charging set.

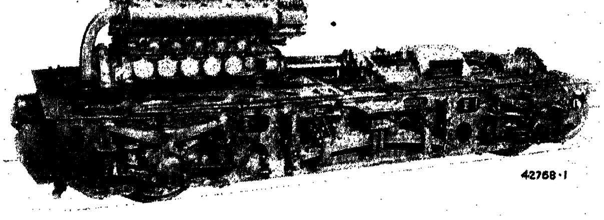


Fig. 159. — Frame of a Diesel engine coach of the German State Railways, driven by a Maybach six-cylinder four-stroke engine.
The engine output is increased by about 50 % by means of the charging set seen in the centre above.

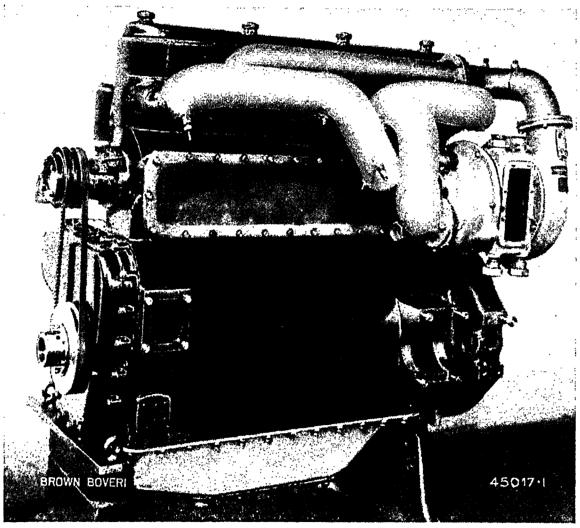


Fig. 160. — 225-H.P. four-cylinder truck Diesel engine by Messrs. Saurer, Arbon (Switzerland), charged by the blower seen on the extreme right.

There is considerable electric equipment required for this type of vehicle. Thus, Brown, Boveri & Cie. A.-G., Mannheim got an order for equipments of this type for 30 four-axle Diesel-fluid-transmission driven motor coaches with Voith fluid gear and for 30 driving trailers. Control of these coaches is electrical and was

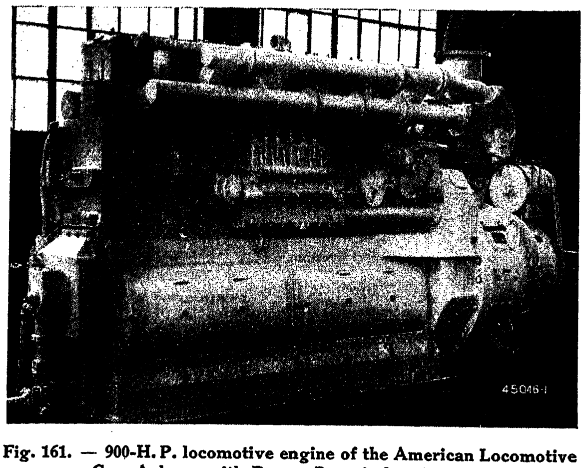


Fig. 161. — 900-H. P. locomotive engine of the American Locomotive Co., Auburn with Brown Boveri charging set.

designed to allow drive from the driving trailer, so that trains made up of two driving coaches and two driving trailers can be driven from one driver's cab. Several of the auxiliary services are also electrically controlled:— the remote supervision of the Diesel engines, the lighting and the hot-air heating. This equipment comprises per coach the following chief parts:— one generator for generating auxiliary current with automatic voltage regulation, two driver controllers, one Diesel injection adjuster for remote control of the Diesel engines, two motors for hot-air heating, one converter set 110/112 V for feeding the Diesel-engine glow plugs, two control-current couplings, a series of measurement and supervision devices. The 30 control coaches each have a driver's cab equipment, two control-current couplings and electric lighting.

V. MARINE DRIVES.

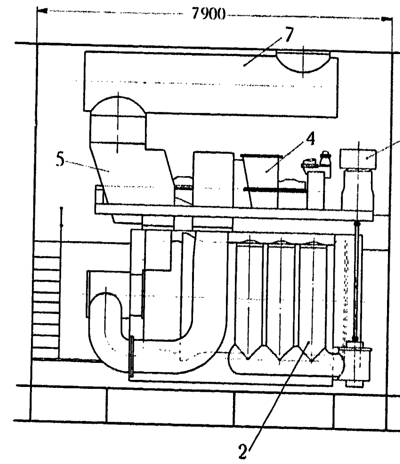
A. VELOX PLANTS ON SHIPS.

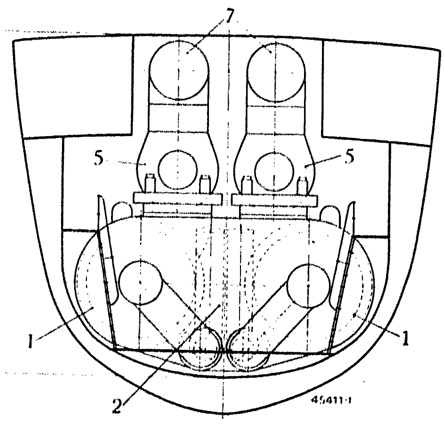
Surprising possibilities as regards the utilisation of the Velox steam generator in naval and merchant vessels have arisen as a result of the wide experience gained in stationary plants and of the constructional progress realized as regards space and weight saving. Thus, investigation has shown that a Velox to produce 80 t/h of steam at 60—80 kg/cm² abs, with all its accessories, only weighs about 55 t and is so small that two instead of the former one boiler of the same output could be lodged in a torpedo-boat boiler room 7 m wide. Thus, the usual boiler space for three boilers allow of using six Velox boilers to produce 480,000 kg/h of steam. The maximum output of a Velox can be kept up continuously without any disadvantage to the Velox itself, or additional power for draught and at the highest efficiency, contrary to what occurs with ordinary marine boilers under forced conditions. Fig. 162 shows the layout in a vessel of two boilers, 80 t/h steam production, as just described. The Velox is placed, horizontally, the steam separator vertically. The charging set (gas turbine, charging compressor and auxiliary turbine) is placed horizontally over the Velox.

We investigated, for ourselves, how a *Velox steam generating plant could have been lodged on the Cunarder-White Star liner "Queen Mary"* and how it would compare with the actual boiler plant. The result is so interesting that we reproduce it in Fig. 163 which shows the striking difference in space required.

TABLE IV.

Data	Actual boilers of Queen Mary	Projected boilers of Velox type
Steam output (continuous) t/h	800	960
Number of boilers	24	12
Length of boiler room in m .	80·5	32·9
Floor area " " " m² .	1962	690
" " " " " m²/t of steam	2·46	0·72
Space up to B deck . . m³ .	26,162	9424
" " " " . . m³/t	32·6	9·8





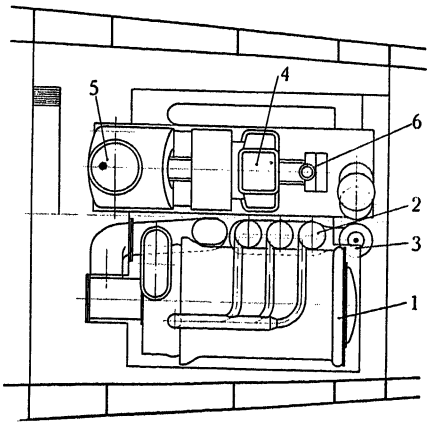


Fig. 162. — Two Velox steam generators built into a torpedo-boat boiler room only 7 m wide and delivering, together, 160,000 kg/h of steam.

The steam pressure is 60—80 kg/cm² abs. The full steam load can be carried continuously without strain on the Velox units. The efficiency at highest load is about 90 % and, at half load 87 %.

1. Combustion chamber.
2. Steam separator.
3. Circulating pump.
4. Charging blower.
5. Gas turbine.
6. Auxiliary turbine.
7. Preheater.

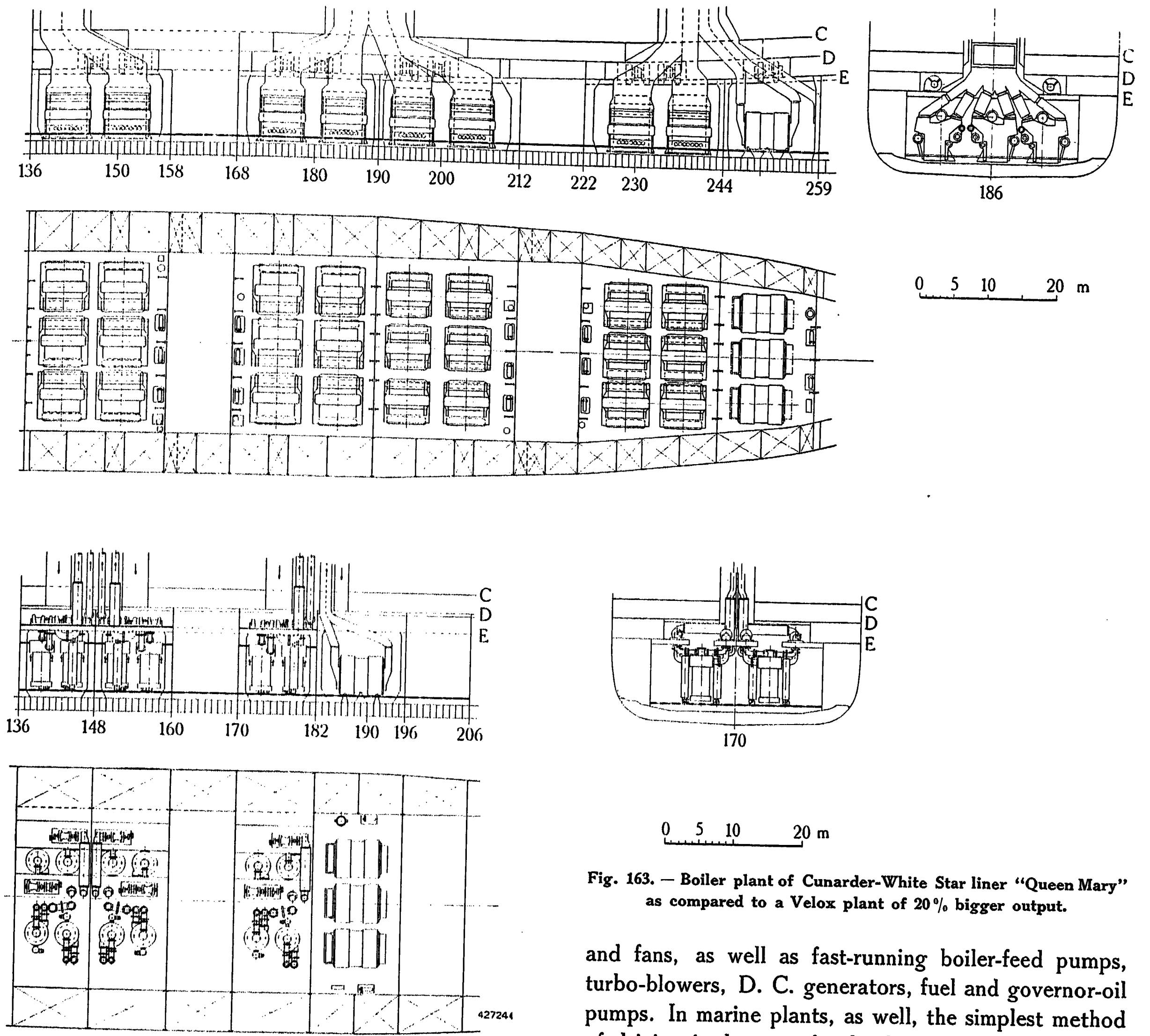


Fig. 163. — Boiler plant of Cunarder-White Star liner "Queen Mary" as compared to a Velox plant of 20 % bigger output.

The Table IV summarizes the chief data for both boiler designs, as far as the main boilers are concerned.

In connection with these figures it must be said that the Velox steam generators suggested are standard units which have already been thoroughly tested, giving a thermal efficiency of 94—95 % and still over 90 % at $^1/_4$ load. This would mean a considerable saving in fuel and less bunker space. The reduced dimensions of the uptakes are, also, worthy of note and the great gain in area on the 'tween decks.

B. MARINE AUXILIARIES AND THEIR DRIVES.

Economical service and operating reliability of the marine boiler and turbine plants depends to a great extent on the quality and reliability of the auxiliaries and their drives, as was pointed out in the case of stationary Velox plants, as well. Among the auxiliaries in question, there are slow-running cooling-water pumps, circulation pumps, condensate pumps and fans, as well as fast-running boiler-feed pumps, turbo-blowers, D. C. generators, fuel and governor-oil pumps. In marine plants, as well, the simplest method of driving is the use of individual, electric drives, the auxiliaries being, then, located at the most suitable points and driven at the speeds most suitable to their individual characteristics. From the economic point of view, as well, electric drive is advantageous especially when it is from a Helux dynamo driven from the main turbine. Unfortunately, the electric drive is not guaranteed against trouble on the electric supply system. The drive of the auxiliaries by steam turbines is much more reliable. As, however, individual drive of the many auxiliaries is unsuitable from the point of view of cost and steam consumption, it is more advantageous to group them together and drive them by a single, bigger and more efficient steam turbine, through reduction gears, each at the speed best suited to it. The disadvantage of this layout is the long connections to and from the pumps, which are, often, difficult to lay. Brown Boveri has created a specially small type of steam turbine for these pumps, taking up little space and running at relatively high efficiency. Pages 69/71

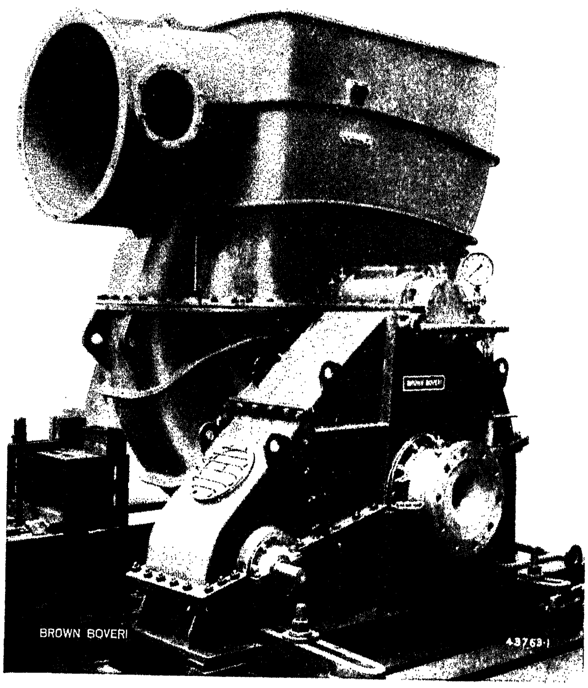


Fig. 164. — Big scavenging blower for a 20,000-H. P. two-stroke marine Diesel engine.

The blower runs at 4000 r. p. m. and delivers 1340 m^3/s of air at 1·35 kg/cm^2 abs. It is driven through a reduction gear by a special 1450-H. P. Sulzer two-stroke auxiliary Diesel engine running at 600 r. p. m. Between the high-speed blower and the Diesel engine subjected to cyclic irregularity there is a flexible coupling having a determined flexible characteristic. This coupling is lodged in the big gear wheel.

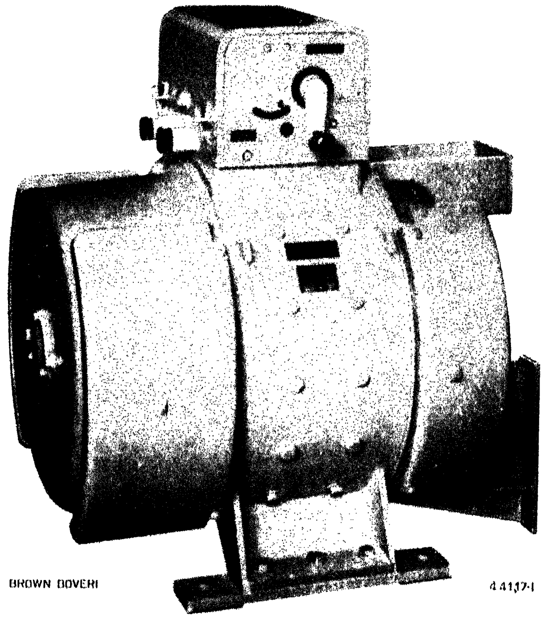


Fig. 165. — D. C. motor, wave-wash proof for drive of a submarine high-pressure compressor, with built-on starter. 83/104 H. P., 110/170 V, 530 to abt. 650 r. p. m.

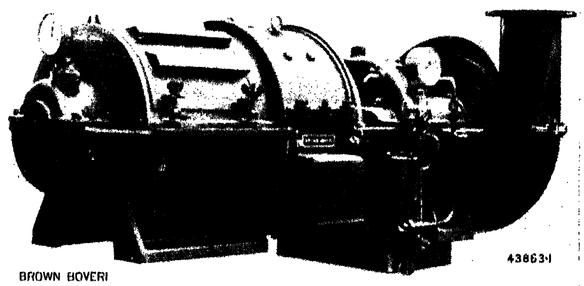


Fig. 166. — Submarine tank blower set, 55 m^3/min, 1·033/1·55 kg/cm^2, 5600/20,800 r. p. m., 80 kW, 110/135 V.

show a large number of marine auxiliaries built by Brown Boveri, which, however, can also be used in stationary plants.

The *scavenging blowers* for marine Diesel engines also belong to the marine auxiliaries. Fig. 164 shows one of two of these blowers for scavenging two 20,000-H. P. two-stroke Diesel engines and which are interesting owing to their size. Each one is driven through a reduction gear by a 1450-H. P. Sulzer two-stroke auxiliary Diesel engine and delivers 1340 m^3/min of air at 1·35 kg/cm^2 abs. There is a flexible coupling in the big gear wheel with a definite spring characteristic, which separates flexibly the fast-running blower, acting like a big flywheel, from the reciprocating engine characterized by its cyclic irregularity.

In the field of *electric drives for auxiliaries* for submarines we have delivered numerous drives for a variety of auxiliary machines and devices. These include a number of starters of special design developed by us (two-pole system cut outs, semi-automatic starting, no-voltage trips, built-in starting resistances). These starters were often combined closely with the motor in question and Fig. 165 shows an example of this.

The high-speed blowers (20,000 to 30,000 r.p.m.) for the submerging tanks of submarines will always be given preference over straight-driven blowers as they are so much lighter. Fig. 166 shows one of latest design of which a large number were delivered in the course of last year.

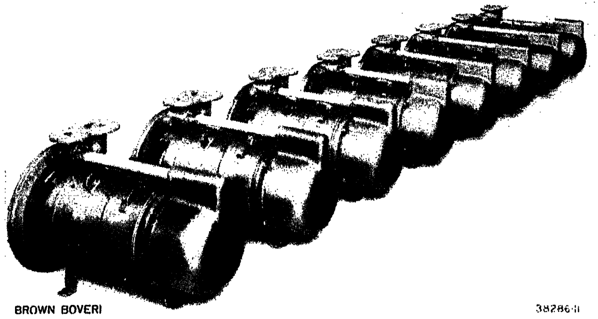
C. ELECTRIC SHIP PROPULSION.

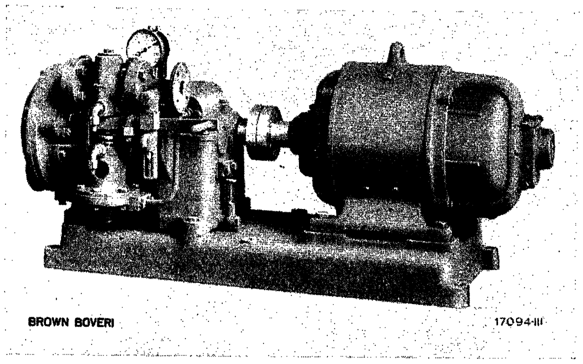
We have gained still further considerable experiences in this field.

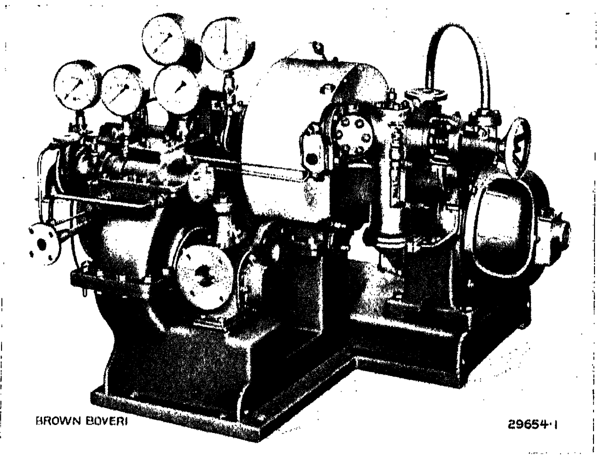
Thus, one of our licencees booked an order for the electric equipment of a Diesel-electric drive for two scouting cruisers. The Ward-Leonard connection is used for control of these plants.

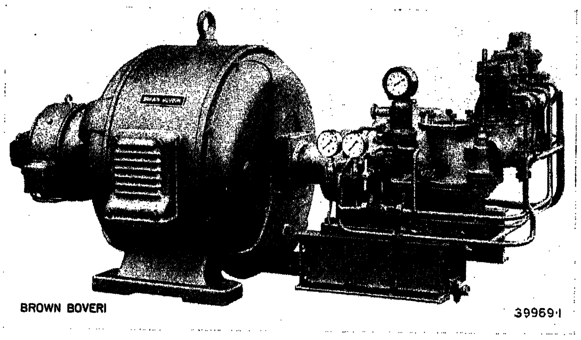
We also got orders for the electric gear for submarines of various navies in the course of last year.

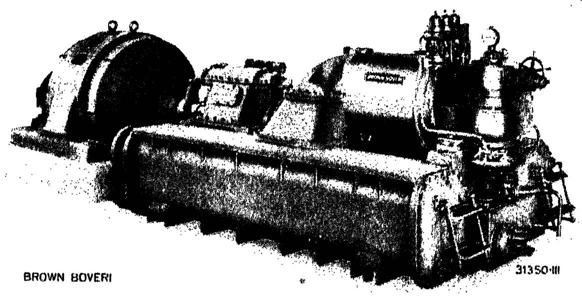
In our last year's report, we were able to mention a *single-screw 9500-t freighter* having Diesel-electric

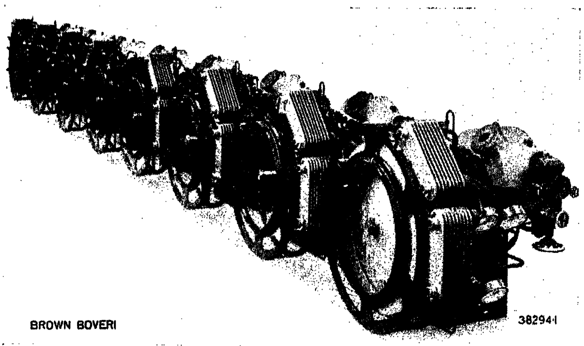


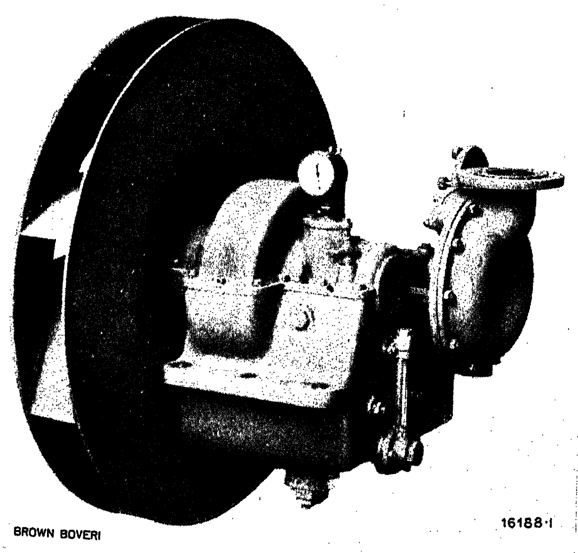


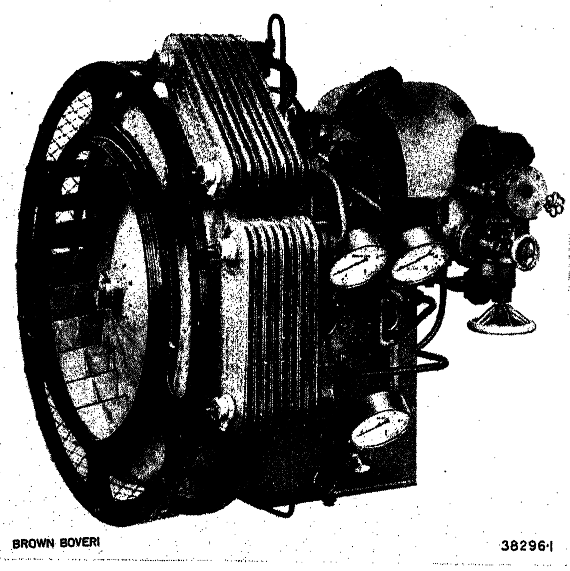




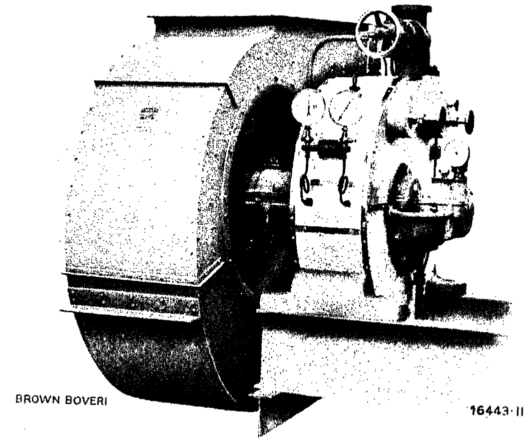


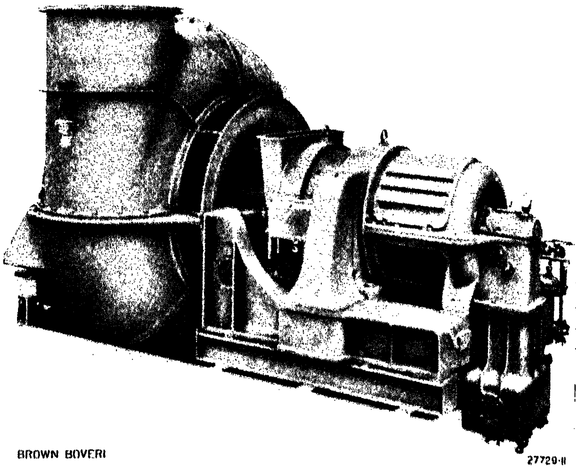


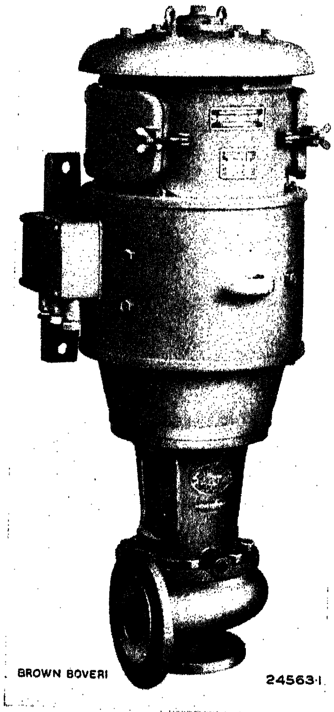


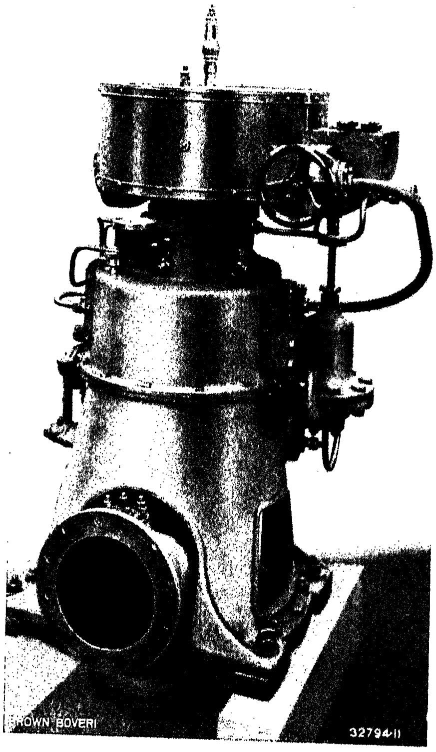


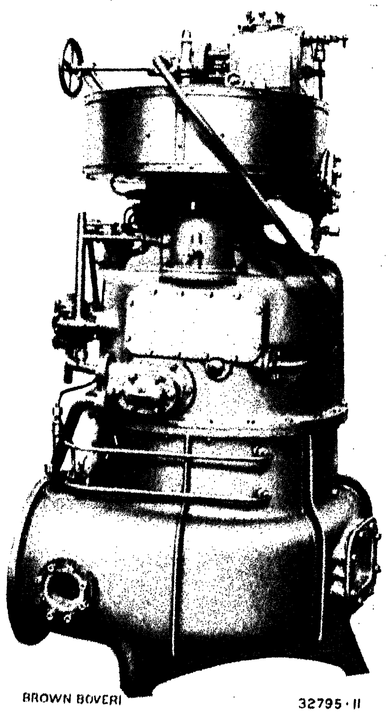
Brown Boveri marine auxiliaries:— Generators for D. C. and A. C. fans.

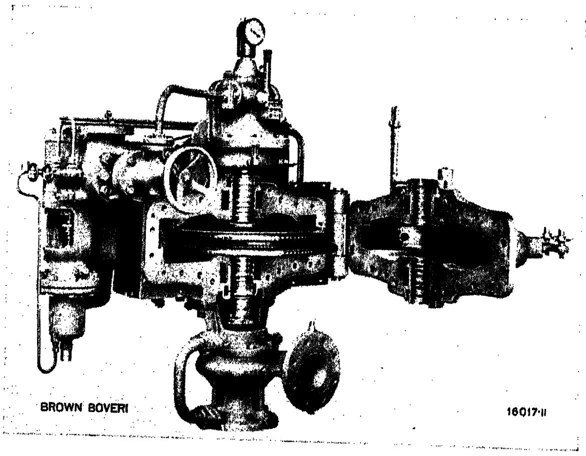


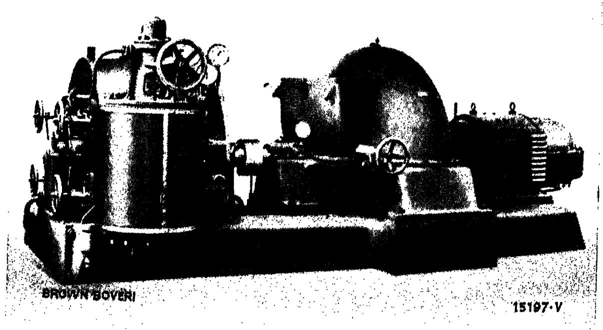




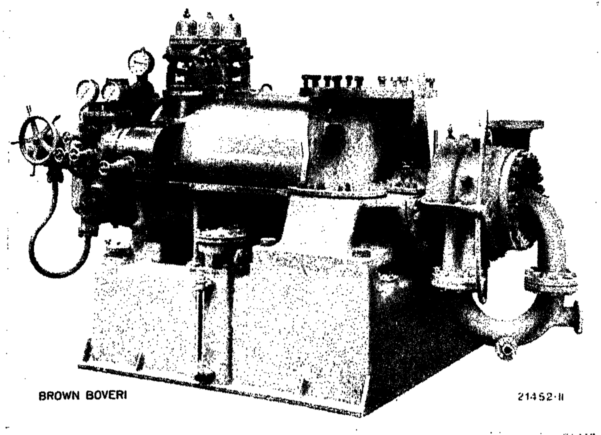


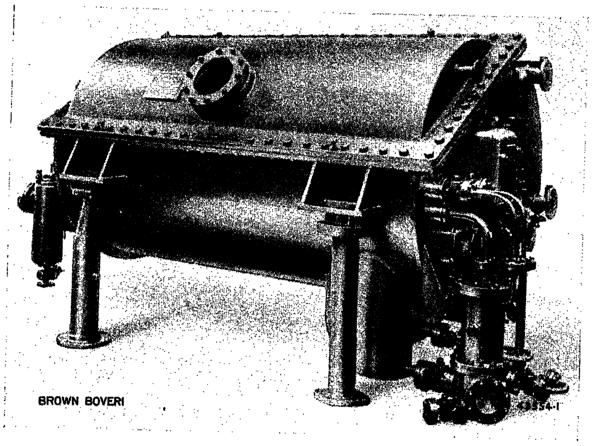


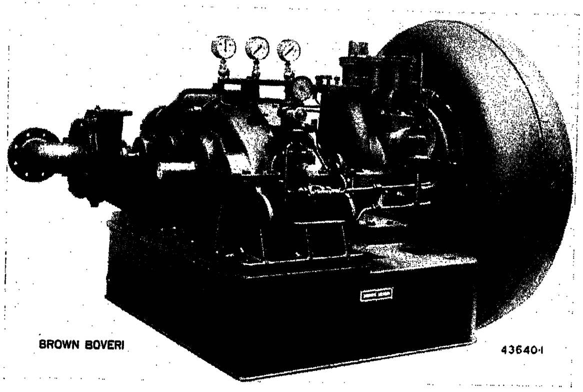


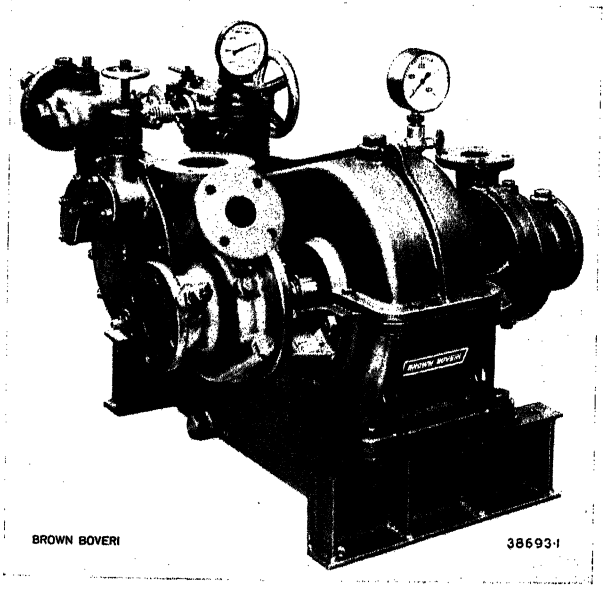


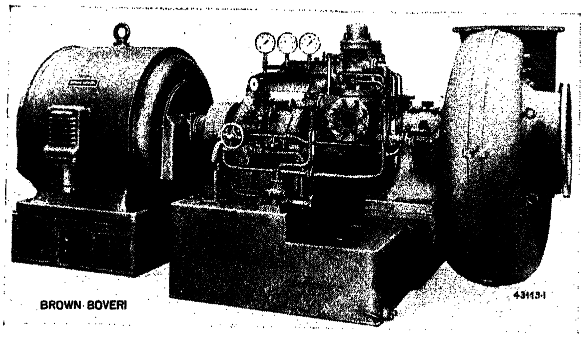
Brown Boveri marine auxiliaries:— Fans, scavenging blowers, feed pumps, circulation pumps (C. E. M.)











Brown Boveri marine auxiliaries:— Feed pumps, pump sets for condensing plants, Frigiblocs.

propulsion, 6800 H. P., which was ordered from Brown, Boveri & Cie. A.-G., Mannheim; this is the first Diesel-electric marine drive built to the system developed by us with A. C. generators working in parallel.

The vessel, the *"Wuppertal"* belongs to the Hamburg-Amerika line and was launched in the middle of Sept. 1936. On the 30th of Nov. 1936 it carried out its maiden trip to Australia. A more detailed description of this drive will be published later and we only desire to say a few words on the subject here.

The main engines are three three-phase synchronous generators each of 1900 kVA, 250 r. p. m., 2000 V, 50 cycles. These are driven by MAN Diesel engines. There is a propeller motor which is composed of a synchronous motor 6800 H. P., 125 r. p. m. and an induction motor of 900 H. P., 62·5 r. p. m. in a common housing. The latter unit is used when much manœuvring has to be carried out or when the vessel has to run slow for long periods and under economical conditions.

There are three converters to excite the machines composed of an induction motor and a D. C. generator,

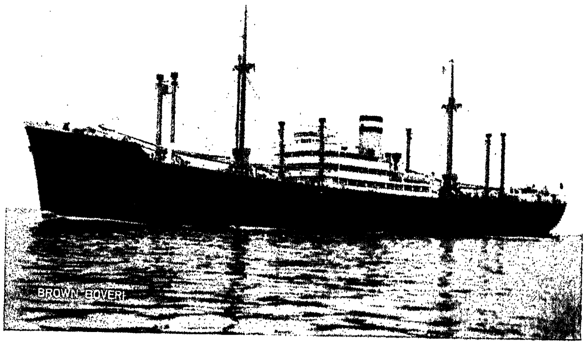


Fig. 167. — Motor ship "Wuppertal" of the Hamburg Amerika Line. With Diesel-electric drive (A. C.) Brown Boveri system.

All auxiliaries below deck as well as lighting are supplied by A. C. three-phase current.

of these, two are required for ordinary service, the third being a spare, or else it can be used for the D. C. auxiliary system.

It is to be noted that the entire auxiliary system of the vessel, pumps, fans, excitation converters, electric kitchen, heating and lighting works under three-phase current; only the deck auxiliaries (winches, capstan for the anchor) are run with D. C. Contrary to the usual custom of using D. C. throughout for such purposes, we have a big vessel, here, using three-phase A. C. for the auxiliaries below deck. There are two Diesel three-phase generator sets 175 kVA each to feed the auxiliaries. However, the system can also be supplied from the bus-bars of the main-driving system through two transformers. This arrangement results in very economical service, at sea, it makes operation simple and saves the auxiliary Diesel engines.

The two main generators suffice for manœuvring so that the third can feed the auxiliaries during that time if it is not desired to make use of the auxiliary generators.

The starting and controlling of the main motor consists in asynchronous starting and then falling into step of the motor when its D. C. excitation circuit is closed. The close regulation of the speed of the vessel is carried out by the speed regulation of the Diesel engines, while wide steps are attained by putting into service one, two or three main generators. The switching in or cutting out of the generators is carried but by simple switching of these units when they are unexcited, which saves time and delicate synchronizing operations.

This marine plant is quite a new departure in marine drives and great expectations are entertained as to the economical qualities of the vessel. Brown Boveri also delivered all auxiliary equipment below deck, that is:— auxiliary motors, remote-signalling plant and installation.

Apart from a big number of submarine drives, we and our licencees have built twelve Diesel-electric marine drives in the course of the last six years. These are given in the following Table:—

TABLE V.

No.	Type of vessel	No. of propellers	Total output on shafts in H. P.	Type of current
1	Fire-extinguishing vessel "Santa Barbara" for Genoa harbour	2	150	D. C.
2	Coastal-defence battle-ship "Wainömoinen"	2	4000	"
3	Coastal-defence battle-ship "Ilmarinen"	2	4000	"
4	Sounding vessel for the River Scheldt	1	64	"
5	Mine-layer "Olav Tryggvason"	2	1400	"
6	Saloon passenger paddle vessel "Genève"	—	920	"
7	Ferry vessel "Bevik-Stathelle" (Norway)	1	60	"
8	Scouting cruiser (building) .	1	570	"
9	Scouting cruiser (building) .	1	570	"
10	Single-screw freighter "Wuppertal" 66 H. A. L. . . .	1	7700	A. C.
11	Ice breaker (building) . . .	3	4000	D. C.
12	Sister vessel to 10	1	6800	A. C.
	Total		30,234	S.H.P.

NOTICE.

It gives us much pleasure to be able to inform our readers that the Swiss Federal Institute of Technology, Zurich, conferred the honorary title of Doctor of Technical Science on its former pupil, our present valued collaborator,

Mr. W. G. NOACK (Dipl. Ing.)

on the 20th November, 1936, on the occasion of the official inauguration of the scholastic year 1936/37. — A decade of creative and constructive work, in the service of our firm, devoted to the whole field of thermal machinery and crowned by the invention and development of the Velox Steam Generator has, thus, found its recognition and well-merited reward.

BROWN, BOVERI & CO., Ltd.,
Baden (Switzerland).

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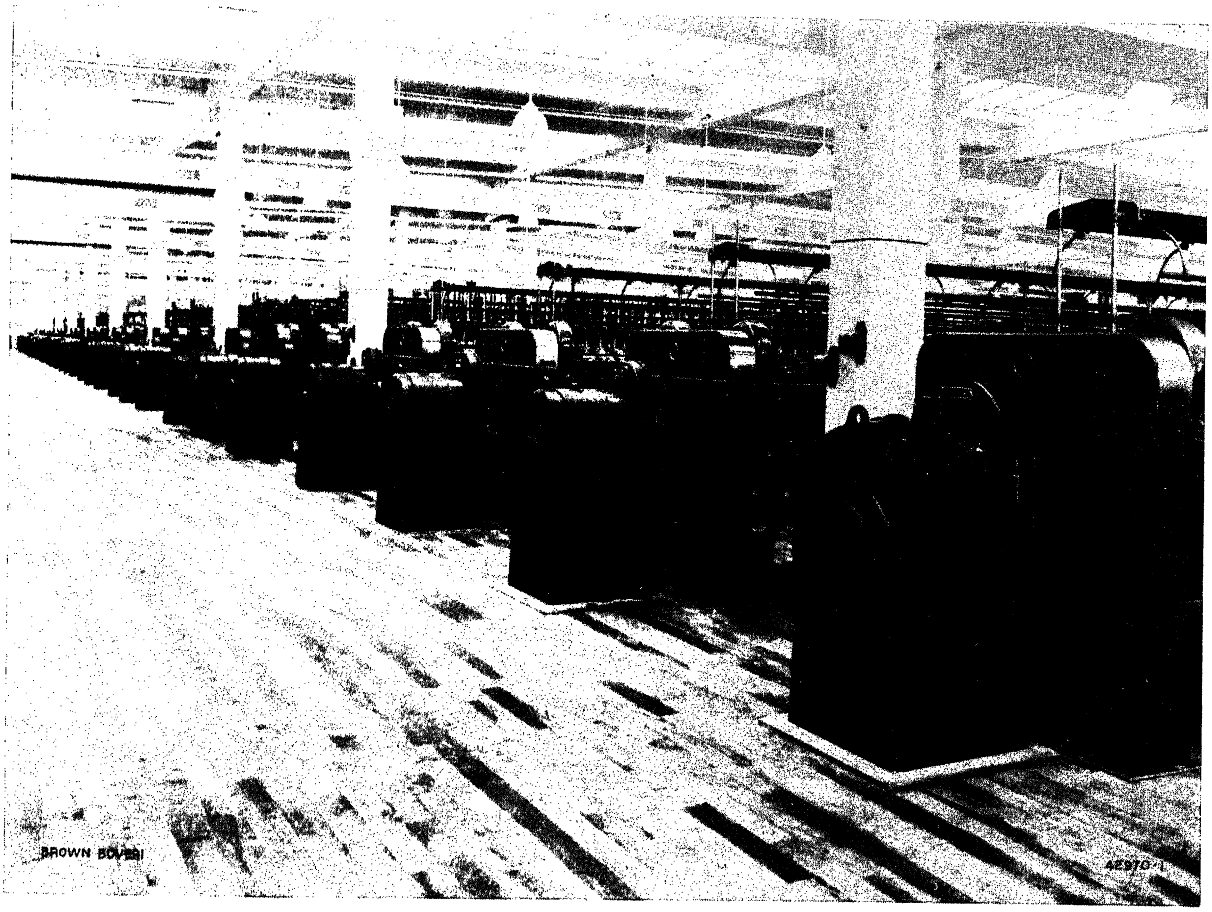
THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)



COTTON SPINNING MILL WITH VARIABLE-SPEED DRIVE FOR THE RING SPINNING FRAMES BY THREE-PHASE SHUNT COMMUTATOR MOTORS WITH SPINNING REGULATORS.

CONTENTS:—

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THE BROWN BOVERI REVIEW

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VOL. XXIV MARCH, 1937 No. 3

THE BROWN BOVERI OIL-PRESSURE TRAVEL REGULATOR FOR BIG ELECTRICALLY-DRIVEN HOISTS, SUCH AS MAIN-SHAFT WINDING ENGINES.

Decimal index 621.34 : 622.67.

I. INTRODUCTION.

THE safety requirements for the operation of the winding equipment of big hoists have become increasingly stringent, as the winding speed has been increased, and the said requirements acquire special importance when the hoist is used for carrying passengers.

One example is chosen, here, from the various classes of big hoists, because it is one which imposes the severest demands as regards faultless supervision of the winding trip, this is the *winding engine* used in shafts and designated as a *mine hoist.* The service conditions of this machine are, both, particular and difficult to meet, there are big forces in play to be dealt with, which are necessary in order to accelerate to high-speed within a few seconds after starting, considerable dead weights (Koepe pulleys, cable drums, reels, the cable itself, hoisting cages and wagons) this apart from the actual accelerating of the heavy loads of material; then, in a hand's turn, all these moving masses have to be braked down in as short a space of time. The continuous variation in working conditions is further accentuated by these cases of load lowering which turn the driving engine into a driven one (negative-load torque). As the winding engine has also got to carry the working shifts of men up and down, the severe conditions imposed, as regards the installation of reliable safety devices against accidents due to too high winding speed towards the end of the wind, are quite justified, this all the more so as, both above and below ground, the amount of overwind travel allowed for is often a matter of a few metres, only.

Safety devices of the kind were provided for at the beginning of the development of hoisting plants. Their feature of reliability generally consists in the tripping of an emergency and safety brake stopping the machinery when the hoist cages overwind or when the speed of the said cages, at certain points of the shaft trips, exceeds the admissible figure. The last condition is the more important the nearer the said control points are to the end of the wind because, in this way, it is possible to make sure that, under the most disadvantageous conditions, the speed with which the cage passes over the normal stopping point cannot exceed a magnitude which allows the emergency brake to stop the cages within the overwind travel allowed for.

This and similar devices protect the hoist against destruction as well as against too much overwinding, but they do not prevent overwinding at speeds which may be dangerous to passengers, under certain conditions. If, as is only correct, it is desired to guard the machine during the whole retardation section of the speed diagram down to the inching speed, in the manner explained above, the requisite device for the purpose would be far too complicated on account of the large number of control points to be built in. Further, this would give rise to undesirable occurrences because, if the adjustments were fairly exact, the safety devices would intervene very frequently; as, however, every intervention of the said devices stops the machine, there would be much time lost which would reduce the carrying capacity of the hoisting plant. These disavantages are more marked the greater the winding speed for material and, especially so when passengers are carried. For example, the State Regulation for Mines in Germany only allows of using tripping devices as safety appliances in the way described when the winding speed for passenger service does not exceed 4 m/s. For higher winding speeds the winding engines must be equipped with safety appliances which are *constantly applied* and the duty of which is to exercise a regulating influence on the machine instead of stopping it by means of an emergency brake when the speed exceeds the speed tolerances allowed for.

The *regulating* influence exercised over an electrically-driven winding engine in such a way as to maintain a speed diagram specified and this during the whole wind, is no longer difficult of accomplishment in the case of D. C. machines in Ward-Leonard connection. As is well known, with this method of control, the winding speed is in direct ratio to the

displacement of the control lever, by means of which the engine-room operator regulates the excitation of the regulating dynamo and, therewith, the voltage impressed on the terminals of the winding motor.

This is termed *natural relationship between lever displacement and winding speed,* and it is thanks thereto that it is relatively easy to supervise and to impose a speed characteristic specified. Nevertheless, this system of regulation requires that certain measures be taken to equalize the voltage deviations in the Ward Leonard circuit caused by the magnitude and direction of the load, if the natural relationship defined above is to be maintained under all circumstances.

If these conditions are fulfilled, the absolute adherence to the winding diagram imposed is attained, by means of a mechanically forward or backward displacement of the control lever limited by, or caused by, the winding engine itself (depth indicator).

The conditions are different with winding engines in which there is no natural relationship between control lever displacement and speed, as for example, when drive is by three-phase motor which is, really, the only one utilized, to-day, for A.C. winding-engine sets. In such cases, it is no easy task to exercise an adjusting influence on the engine with the object of suiting the actual speed to a value specified in advance, when the said adjustment of the speed has to be produced for every magnitude and direction of the load and be exerted over the whole range of the wind.

By following the method mentioned before of imposing on the control lever a backwards movement from its running to its dead position, no specified speed reduction diagram of the engine can be attained; on the contrary, when the load torque is negative the contrary of what is desired may occur on account of the electric properties inherent to the three-phase motor. Centrifugal-force static governors do not solve the problem in anything like a satisfactory manner, because all devices of this kind have the fundamental drawback that for the same speed excesses they are characterized by a short-displacement *travel* in the range of high speeds and by developing low displacement *forces* in the lower speed ranges; in other words they are insensitive in both cases and will fail when most needed, namely when the speeds are low and when they are lowest, i. e., during the overwinding travel, at the end of the wind.

In the following paragraphs the *oil-pressure travel regulator* developed by Brown Boveri is described and it will be shown that a safety apparatus has now been created which fulfils, to an exceptional degree, all the requirements of heavy winding-engine service.

II. HOW THE BROWN BOVERI OIL-PRESSURE TRAVEL REGULATOR WORKS.

The way in which the Brown Boveri oil-pressure regulator works is explained here with the help of Fig. 1.

ZP is a gear pump delivering oil and driven by that shaft the speed of which is to be supervised; although this pump reverses its sense of rotation along with that of the said shaft, it continues to deliver oil in the same sense, being equipped with reversing valves. The quantity of oil it delivers increases, in direct ratio to the speed, while the pressure depends on the resistance of the circuit for the quantity of oil being circulated. The oil delivered is led under the spring-loaded piston I in cylinder A and forces the piston to move through a certain stroke. The magnitude of this stroke, for a given driving speed of the pump, depends on the oil pressure produced under the working piston and on the characteristic of the counter-spring F. If a determined piston stroke is to correspond to a determined speed of the driving shaft and remain constant for that speed, measures must

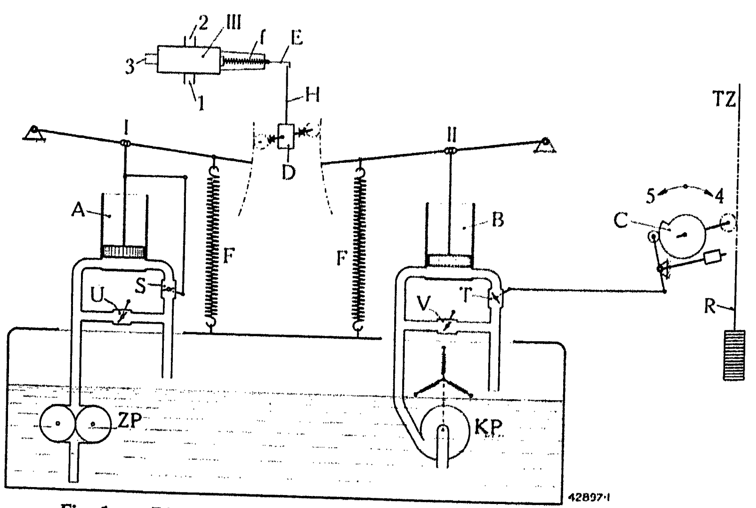


Fig. 1. — Diagram of the Brown Boveri oil-pressure travel regulator.

A. Stroke of piston I.
B. Stroke of piston II.
C. Control cam of valve T of the "specified-speed" piston.
D. Mechanical differential gear.
E. Rod of control valve.
F. Power-storage spring.
f. Recall spring.
H. Lever actuated from differential.
KP. Centrifugal pump.
R. Driving rod for actuating the control cam of the "specified-speed" piston.
S. Control valve for limiting stroke of "actual-speed" piston.
T. Control valve for limiting stroke of "specified-speed" piston.
U, V. Adjustable cocks on oil circuit.
ZP. Gear pump.
I. "Actual-speed" piston.
II. "Specified-speed" piston.
III. Pneumatic brake-pressure regulator.
1. Inlet.
2. To brake cylinder.
3. Exhaust.
4. Sense of displacement of cam curve for starting.
5. Sense of displacement of cam curve for stopping.

be taken so that the pressure under the working piston cannot increase further as long as the gear pump runs at the said constant speed. This is attained by means of a given opening of the value S the amount of which is made to depend on the stroke of the piston.

A low speed of the gear pump causes a small volume of oil to be delivered, a low pressure to be established under the piston and a short stroke to result. If the speed of the pump increases, the amount of oil delivered increases and with it the pressure and the travel or stroke of the working piston. To each speed of the winding engine between zero and maximum, there is a determined stroke of the piston. *It can be said that the stroke of piston I is a direct measure of the "actual speed" of the winding engine.*

KP is a centrifugal pump, electrically driven and always running at constant speed. It also delivers oil under a spring-loaded piston II which moves in cylinder B. The pressure under this piston and, therefore, its stroke, is adjusted by throttling the oil-circulation flow by means of valve T. The latter is governed by a cam disc C, the profile of which is cut to correspond to the speed characteristic specified in advance for the winding engine. This cam is controlled by the hoisting gear. *By making the opening of valve T dependent on the position of the hoist cage, the stroke of piston II gives a measure of the "specified" speed.*

If now, the two spring-loaded pistons are made to influence a differential gear D, there will be no deviation of the latter when the two piston strokes are identical; if, however, one stroke differs from the other, there is a deviation of D in one sense or the other.

The deviation of the differential can now be made use of to produce a switching or working process, as in the present case, where it is utilized to actuate the pressure regulator of a compressed air brake.

The special quality to be stressed here is that the braking produced by the deviation of the differential can be utilized during the slowing-up period, down to the practical inching speed. This is because the adjusting force to be produced for this braking is exercised directly by a power storage spring F, and this without a servo-motor. The discharge of the said power-storage device is all the more active, the smaller the counter oil pressure which opposes it during the slowing-down period on the "specified" speed side. This characteristic of the Brown Boveri oil-pressure travel regulator even leads to the application of the brakes if a leak occurred in the oil tank common to both pumps and the oil drains away.

III is a brake-pressure regulator valve which applies pressure to the hoist brake proportionately to the displacement of its control rod E.

As soon as the brake pressure is applied to the winding engine, its "actual" speed falls, therefore, the differential lever H moves towards its medium position again and releases the recall spring on the pressure regulator valve of the brake, so that the regulating rod E can be drawn in by the said spring and the brake pressure reduced. For the condition "actual" = "specified" speed the pressure regulator III comes back to the neutral position again.

If, on the contrary, the "actual" speed should be lower than the "specified" speed, piston II predominates. The result is that the differential deviates in the opposite sense. As, however, in this case there should be no application of brakes the apparatus is so designed that the differential then swings free, i. e. does not actuate the brake-pressure regulator.

U and V are throttle cocks inserted on a by-pass pipe to the main oil circuit. The first duty of these cocks is to allow of setting the piston stroke to the desired value to suit the power-storage characteristic of the spring this by being opened for a given amount of throttling; further, by adjusting one or other of these cocks to a stronger or weaker throttle effect, it is possible to adjust the maximum speed limits for which the travel regulator is set either upwards or downwards. When for example, the speed for carrying passengers has to be lower than for material alone, cock V is open further so that, the power-storage pressure being the same, the travel of the "specified speed" piston is smaller and is caught up and passed by the "actual speed" piston, already at a still lower "actual" speed.

In emergencies, the throttle valve V can be adjusted from the operator's post or from one of the platforms, this either mechano-pneumatically or electro-magnetically.

The possibility thus presented of being able to adjust as desired maximum speed limits is, further, of great importance from a constructional point of view, as it means that one and the same model of travel regulator can be used for all speed conditions and loads.

Fig. 2 shows, diagrammatically, how the travel regulator is built into a main-shaft winding engine, driven by a three-phase motor and equipped with a standard A. C. control of the Brown Boveri type. The behaviour of the travel regulator will be made clear with the help of the diagram in question:—

(a) *Engine stopped.*—The "actual speed" piston I is in its lowest position the stroke of the piston is

zero, because the gear pump is not running. Valve S is in the position of maximum throttling.

The "specified speed" piston II is very slightly raised, its centrifugal pump is running at constant speed, but the oil it pumps circulates freely as the cam C on the depth indicator sets the throttle valve T in the position of minimum throttling.

The result of this is a position of the differential D such that its lever arm H does not come in contact with the valve E of the pressure regulator and the latter is in the position of air exhaust. There is a slight play X between H and the point to be actuated on the valve-rod of the pressure regulator.

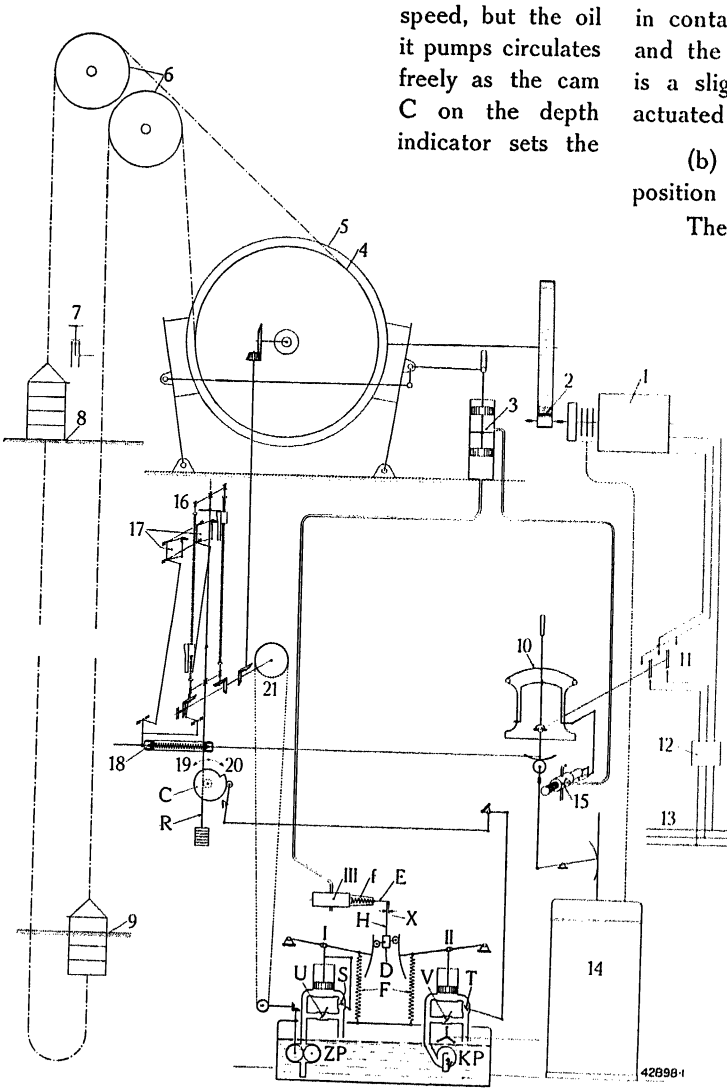


Fig. 2. — Diagram of the travel regulator built into a main-shaft winding engine driven by a three-phase motor.

1. Three-phase winding-engine motor.
2. Reduction gear.
3. Double brake cylinder for service brake and for travel-regulator brake.
4. Koepe pulley.
5. Brake rim on the Koepe pulley.
6. Cable pulleys mounted in shaft frame.
7. End-travel switch to release emergency brake when overwinding occurs.
8. Discharge platform for material on surface.
9. Filling station for material underground.
10. Single-lever control pedestal.
11. Stator winding switch of winding motor.
12. Switchbox.
13. Supply system.
14. Hot-water starter of winding motor.
15. Regulator of brake pressure for the service brake.
16. Depth indicator.
17. Mechanical recall apparatus of control lever.
18. Spring device.
19. Sense of displacement of cam curve C for starting.
20. Sense of displacement of cam curve C for stopping.
21. Chain drive of gear pump of the "actual-speed" piston.

C. Cam curve controlling valve T of the "specified-speed" piston.
D. Mechanical differential gear.
E. Rod of control valve.
F. Power storage spring.
f. Recall spring.
H. Lever actuated by differential.
KP. Centrifugal pump.
R. Driving rod of cam control of "specified-speed" piston.
S. Control valve to limit stroke of I.
T. Control valve to limit stroke of II.
U, V. Adjustable cocks on the oil circuit.
X. Play allowed.
ZP. Gear pump.
I. "Actual-speed" piston.
II. "Specified-speed" piston.
III. Pneumatic brake-pressure regulator.

(b) *Starting.*— Throttle valve V is set to the position "hoisting of material".

The engine starts. The "actual speed" piston begins to work, H moves round in clockwise sense and catches up play X; at the same time rod R on the depth indicator sinks and cam C causes increasing throttling of valve T. *If the operator starts the engine properly the lever H of the differential D will not deviate much to either side,* and certainly not so that the brakes are actuated after surmounting the idle stroke of the pressure regulator.

If, however, the operator starts too quickly, the stroke of the "actual speed" piston dominates that of the "specified speed" piston, H acts on the pressure regulator and this causes the brakes to be applied, as powerfully and *for as long as is necessary for the "actual" speed to become equal to the "specified" speed.*

At the end of the starting cycle, the rod R on the depth indicator stops and the throttling of valve T has attained the maximum and will not be modified for the time being. If for any reason, the "actual" speed exceeds the "specified" speed during the course of the wind, the brakes are applied in the way already explained.

(c) *Stopping.*— Towards the end of the wind, at a given point of the travel of the travelling nut on the depth indicator, the control handle is brought back automatically to the negative displacement zone (braking zone). In its backwards movement, as soon as it has exceeded the neutral position, the stator winding of the winding motor is cut out and the next moment, when the negative displacement of the lever begins, the stator phases are interchanged and connected up to the supply again with the result that a progressive braking

process of the engine, by counter current is initiated. A spring device in the recall rod of the control lever allows the operator to damp down the counter-current braking and to hold to the retardation speed diagram desired. Shortly after the backward movement of the control lever has been initiated, however, the rod R is carried along with the travelling nut which is coming up and, as a result thereof, a decrease of the throttling of valve T on the "specified speed" piston through the intervention of cam C is initiated.

In the case of insufficient retardation, the operator has to expect the intervention of the travel regulator, as soon as the margin adjusted for is exceeded by the "actual" speed of the winding engine, but this only in the above case, because, otherwise, the travel-regulator brake remains released, that is when retardation is according to programme or is too great, because, in this case, lever H of the differential does not actuate the pressure regulator, as was explained before. *Despite this, it is impossible for the operator, after an initial too strong retardation, to accelerate the engine again above a value corresponding to a "specified" point in the retardation diagram, because the reduction of the throttling of valve T on the "specified speed" piston is dependent on the depth indicator.*

At the end of the retardation, the operator lays the control lever "across" and thus causes the service brake to be applied, which is independent of the travel regulator; he then guides the control lever along the brake edge back to the neutral and stop position: Brown Boveri single-lever control.

The control process is exactly similar for load lowering instead of load hoisting. In this case, however, the engine is subjected to a negative load torque which may be strong enough to make the engine rotate. This, however, does not affect the operation of the travel regulator at all; when the speed specified is exceeded the said regulator causes infallible braking, whatever magnitude of load or sense of load travel may be, on which factors only the duration and severity of the braking depend.

III. BEHAVIOUR OF THE TRAVEL REGULATOR WHEN FAULTY CONTROL OPERATION OF THE WINDING ENGINE TAKES PLACE.

The behaviour of the travel regulator when faulty control operations are carried out is of great importance. Among the possible occurrences, and not the worst one, is the case of the winding-engine operator being incapacitated or suffering from a stroke during the wind, when passengers are carried. Modern winding engines are protected against eventualities of this kind by safety devices, which work automatically and relatively simply, through the application of emergency brakes which stop the winding engine before the cage has reached the end of the wind. Faults due to carelessness or distraction on the part of the operator can be far more dangerous and these must be taken account of.

It should be stated in this respect that:— *the Brown Boveri travel regulator protects the hoist in the most unlikely eventualities, even in the case of intentional sabotage by willful counter measures on the part of the operator.* The travel regulator has given brilliant proofs of its value under the severest tests in practical service.

We give here some data on these exceptional tests, supported by registered data (Fig. 4).

Diagram 1 is of normal winds with about 4 t useful load at 10 m/s from

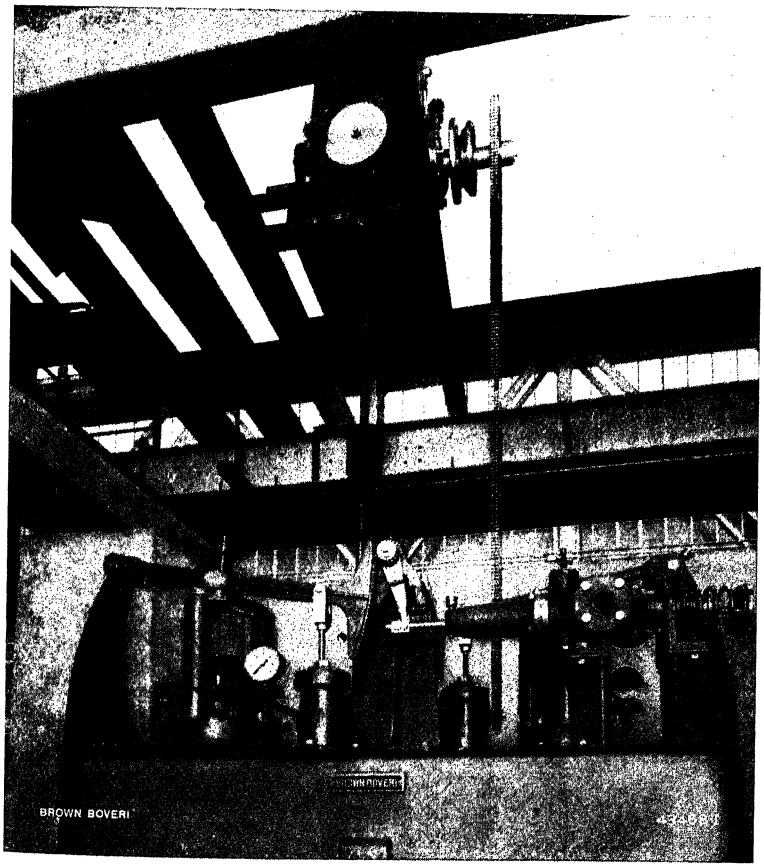


Fig. 3. — Oil-pressure travel regulator mounted:— Depth indicator and drive of "actual-speed" piston and control cam of "specified-speed" piston.

a depth of 585 m. The load torque is constantly positive. The travel regulator was never called on to act because the operator controlled the engine properly and was never corrected by the travel regulator. The slowing-down speed at the end of the wind was, further, very low and less than 0·5 m/s.

Diagram 2 shows the brief intervention of the travel regulator at the end of the wind, because the operator did not apply strong enough counter braking. If there had not been a travel regulator, the cages would have overwound at about 2 m/s. The travel regulator acted, because the speed was still about 2·5 m/s instead of about 2 m/s at a certain point near the end of the wind. No overwind took place.

Diagram 3.—In this case a load of 2700 kg (corresponding to 36 men) was lowered at a speed of 10·6 m/s. The rotor of the three-phase motor got short-circuited, in the process. The travel regulator does not intervene yet as the super-synchronous speed attained is still within admissible limits. The slow down is regulated by counter-current braking by the operator. This load was the one held to for all further tests.

Diagram 4.—The same load lowered is used but after the short-circuiting of the rotor of the motor, the control handle is *left to itself*. The machine was brought to a stop softly and according to prescribed service conditions by the automatic bringing back of the control lever to the negative displacement (counter-braking position). After the bringing to a stop by counter-current braking, the safety brake applies again automatically and prevents a restarting of the engine in the other sense.

Diagram 5.—The same load lowered is used again but after attainment of the super-synchronous speed the control lever is brought back to the medium position and the driving motor deprived of current. *The cage continued to travel to the end of the wind under no current*, because the control lever was maintained forcibly in the neutral position when the brakes were raised and the automatic retardation process by mechanical movement backwards of the lever to the counter-current braking zone was *intentionally prevented.*

The travel regulator intervened at once, and first assured no exceeding of the maximum allowable hoisting speed by application and lifting of the compressed-air regulating brake, it also stopped the engine smoothly and correctly at the end of the wind.

Diagram 6.—The same load lowered, as before *but, this time, the motor is deprived of current from the start and the brakes are not applied.* The travel regulator again allows attainment and maintenance of the maximum allowable speed and stops the engine in the desired way by progressive retardation.

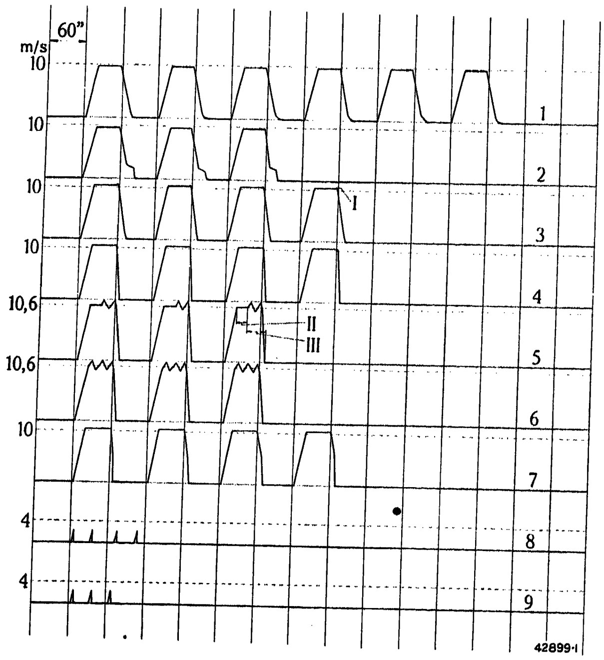


Fig. 4. — Test diagrams.

I. Transition from generative braking to counter-current braking.
II. Generative braking.
III. Travel-regulator braking.

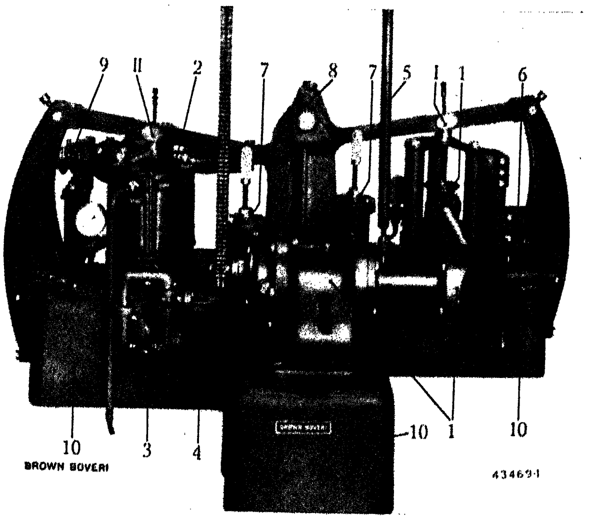


Fig. 5. — View of oil-pressure travel regulator from the driving side of the "actual-speed" piston.

I. "Actual-speed" piston.
II. "Specified-speed" piston.
1. Gear of piston I.
2. Electric motor of piston II.
3. Oil-circulation valve.
4. Control valve T of piston II.
5. Control rod of valve T of piston II.
6. Control rod of valve S of piston I.
7. Power storage.
8. Mechanical differential gear.
9. Pneumatic brake-pressure regulator.
10. Bedplate designed as oil reservoir in which the gear pump and the centrifugal pump are lodged.

Diagram 7.—A wind is carried out in which the control lever is not set on the neutral point and the motor is not deprived of current *but, intentionally, the lever is pushed over to its maximum displacement and prevented by force from coming back to its counter-braking zone.* The driving motor thus carries the supply current. On approaching the end of the wind, the cam curve causes the "specified-speed" piston of the travel regulator to act, the speed is immediately braked down till the current increase causes the safety brake to trip and apply.

Diagram 8.—The loaded cage is at the landing stage (running out the wagons at end of the wind).

The operator gives *full* power in the *wrong* direction, i. e. to overwind.

The control curve of the cam of the "specified-speed" piston is at the extreme point of its excentricity and has brought valve T to minimum throttling. As a result the "actual" piston will immediately apply the brakes. In the present case, the overwind travel including *travel under brake application was only about 3·0 m.*

Diagram 9.—As in diagram 8, but the loaded cage is at the loading point which is the most dangerous case. *Again the operator gives full power intentionally in the wrong sense.* The maximum overwind travel, *including that under brake application* was only about 3·5 m. In both cases, of course, the safety brake was cut out.

These tests show, most clearly, that the Brown Boveri oil-pressure travel regulator protects winding engines in exceptionally comprehensive manner against failures in service. *Nothing occurs as long as service is carried on in the normal way while when there is a failure of the operator and, if necessary, against the will of the latter, it takes charge of the winding engine.*

IV. AUTOMATIC CUTTING OUT OF THE OIL-PRESSURE TRAVEL REGULATOR DURING THE WIND.

Although the condition was imposed that the travel regulator had to supervise the load on the whole of the winding trip, this does not exclude the fact that the work of the travel regulator during the starting period (we would stress only during the starting period) may be undesirable. If no measures are considered necessary to protect the electric machines against too high peak loads, an imposed limited starting process within the maximum speed limit is, really, not a necessity and it may be a drawback, from the economic point of view. Even if a special cam curve for the "specified" speed had been provided, the switching in and out of this cam at the proper moments introduces quite serious modifications of the otherwise simple travel-regulator system, so that *the proper starting process has to be bound to the retardation curve imposed.* Either the control cam curve of the "specified" organ of the travel regulator must be so stepped that it permits of a free start, or else the start must be as carefully carried out as the retardation. In the first case, the ideal supervision of the slowing-down section of the winding diagram *down to the practical inching speed* is seriously impaired, because the throttling positions of the by-pass valve of the "specified" piston would have to allow for a free start, while, in the second case, there is a starting process continuously disturbed by the intervention of the travel regulator, to a degree which becomes inadmissible.

Experience shows, further, that when there is a pressure of work on the winding engine, there is little attention paid on the main shafts of mines to careful starting. The natural urge to catch up on the unavoidable traffic blockages under ground by overloading the winding engine would also lead, too easily, to attempts to influence the last section of the winding diagram, if the travel regulator did not set limits which are absolutely necessary.

To take the preceding considerations into account, the Brown Boveri oil-pressure travel regulator can be perfected by a device which allows of cutting it out, partly or entirely, from the start of the winding engine until full speed has been attained. This is carried out automatically without the operator being made aware of it. The travel regulator is neither uncoupled or put out of service, it works on but in such a way that the "actual-speed" piston always lags behind the "specified-speed" piston, so that the lever of the differential never makes contact with the pressure regulator of the brake.

To this end, the throttle cock U (Fig. 1) of the "actual-speed" piston is regulated according to the sense of rotation of the machine and to the corresponding sense of travel of the shaft cages and in such a manner that, during the starting period, it is far enough open and allows so much oil to pass that, when the start is not excessively abrupt, the "actual-speed" piston is always behind the "specified-speed" one. As soon as full speed has been attained, or the starting period terminated or if the machine is switched over during the starting period, it comes back under the control of the travel regulator again.

In the present case, the control of cock U is electro-magnetic but it could be carried out, just as well and without difficulty, in a mechanical way.

Fig. 6a represents the relationships between the displacement of the control lever, the sense of rotation

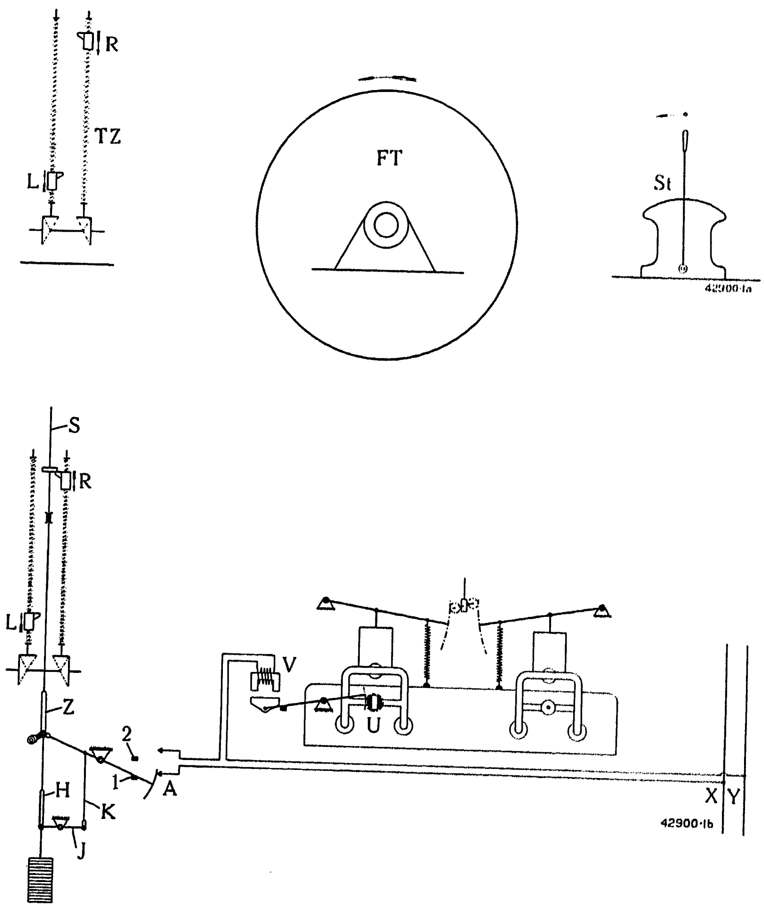
of the machine and the movement of the travelling nut on the depth indicator for ordinary service conditions. According to this diagram and when seen from the machine shaft end the following conditions are attained:—

For the forward movement:— *right* depth indicator (right cage) *downwards.*

For the reverse movement:— *right* depth indicator (right cage) *upwards.*

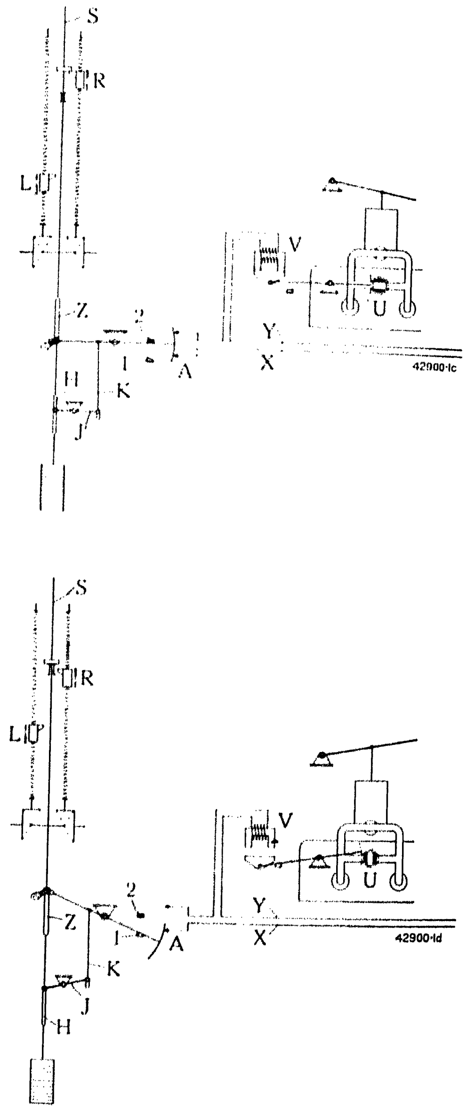
Fig. 6b shows the control in the rest state, ready to begin a new wind. This new wind is in the sense of a forward movement of the engine, the right travelling nut R will, then, move downwards.

(a) *Start: forward movement.*—As soon as the machine starts, the nut R moves on the depth indicator downwards and allows the rod S to sink. At the beginning of the lowering movement, the rod S brings the cut out switch A to the closed position,



Figs. 6a and b. — **Diagram of device for automatic cutting out of the oil-pressure travel regulator during the starting period.**

St. Control lever pedestal.
FT. Winding drum.
TZ. Depth indicator.
R. Right travelling nut.
L. Left travelling nut.
S. Driving rod for control cam of the "specified-speed" piston and also the device to by-pass the travel regulator during starting period.
Z. Slip sleeve.
H. Longitudinal slit.
J, K. Transmission levers.
1, 2. End-travel stops.
U. Cock for oil circulation on the "actual-speed" piston.
V. Electro-magnet.
X,Y. Bus-bars, system.
A. Switch.



Figs. 6c and d. — **Diagram of device for automatic cutting out of the travel regulator during the starting period.**

St. Control-lever pedestal.
FT. Winding drum.
TZ. Depth indicator.
R. Right travelling nut.
L. Left travelling nut.
S. Driving rod for control cam of the "specified-speed" piston and also the device to by-pass the travel regulator during the starting period.
Z. Slip sleeve.
H. Longitudinal slit.
J, K. Transmission levers.
1, 2. End-travel stops.
U. Cock for oil circulation on the "actual-speed" piston.
V. Electro-magnet.
X,Y. Bus-bars, system.
A. Switch.

through the agency of slip-sleeve Z, which causes the coil of the electro-magnets V to form the closed current circuit X—A—Y (Fig. 6c). Under these conditions, i. e. when the coil is under voltage, the electro-magnet has opened cock U wide so that a great deal of oil can flow off freely.

These conditions are maintained until the end of the starting period, i. e. until the rod S has sunk so far that its longitudinal slit H, acting through lever J and rod K, has forced the switch A back to its open position (Fig. 6d); then rod S comes to a stop, the coil of V is dead and allows weight or spring-loaded cock U to fall into the throttling position for service and brings the "actual" piston into a position of equilibrium with the "specified" piston. From then, onwards, the winding trip is controlled by the travel regulator.

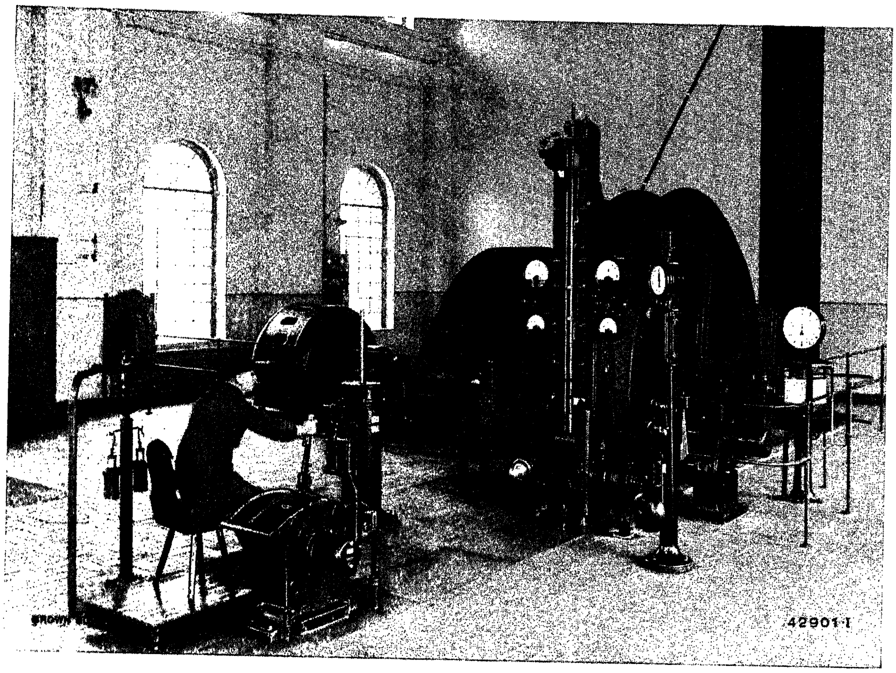


Fig. 7. — Kohlenbergwerk Gewerkschaft Castellengo-Abwehr, Gleiwitz, Upper Silesia. Winding engine of the Concordia shaft. Hindenburg.

Winding motor: Three-phase, 6000 V, 50 cycles, 600 kW continuous-load rating.
Depth: 586 m.
Useful load: abt. 4000 kg.
Winding speed: 10 m/s.

The travel regulator is under the floor. In the illustration, its drive by chain and the control cam curve for the "specified-speed" can be seen.

(b) *Slowing down at end of trip.*—This is started by the travelling nut L coming up when it begins to raise the rod S by which the cam of the "specified" piston stops the rise of the latter. This upward-movement has no effect on the control switch A of coils V, as, at the most, the switch is pressed further home on its contact 1 while the slip sleeve passes through.

(c) *Reversing during the starting period.*—If the engine is reversed during the starting period, it must come under the control of the travel regulator again as soon as the reverse movement towards the wind end (landing stage) begins. This happens in any case because the control switch A follows the reversal in the displacement of S and is immediately opened for an upward movement of S so that electro-magnet V is deprived of current and the cock U falls back to the standard service setting.

According to the amount of throttling of cock U, the action of the travel regulator during the starting period can be made to be *completely* cut out or *partly cut out.*

V. CONCLUSIVE REMARKS.

The preceding comments make it easy to understand that, by suitable modification, the equalizing system described can be used for other purposes where a prescribed speed diagram is necessary.

As in the case discussed here, the travel regulator can regulate through the action of a finely graded brake (which may be an electric one); it can, however, also be used, in special cases (such as big automatic lifts) in such a way that the deviations of the differential in one sense cause braking and in the other produce acceleration, in the latter case by acting on the driving engine.

The Brown Boveri oil-pressure travel regulator was approved of by the Reich and Prussian Ministry for National Economy on the 18th of April, 1936 on the basis of officially supervised tests carried out on a winding plant built by Brown, Boveri & Cie. A.-G., Mannheim.

(MS 524) *A. Schorno. (Mo.)*

THE MOTOR EQUIPMENTS OF THE FABRIK FÜR FIRESTONE-PRODUKTE A.G. IN PRATTELN (SWITZERLAND).

Decimal index 621. 34 : 678.

THE pneumatic-tire manufacturing plant "Fabrik für Firestone-Produkte A. G." was completed in the spring of 1935, having been built in the relatively short period of 135 days. This plant is laid out for a daily production of 400 tires per day. The electric plant for providing the requisite power and nearly all the motor equipments in the shops were built by Brown, Boveri & Co., Ltd., Baden and presented some interesting problems for solution which are reported on in the following paragraphs.

The manufacturing process in a tire works will first be explained with the help of the diagram of Fig. 1.

As a complete pneumatic tire is composed of an inner tube and a cover, there are two quite separate manufacturing processes being carried out independently, although in parallel with one another:— the tire-cover manufacture and the inner-tube manufacture. As, however, the tire cover itself is built up of different layers of rubber and rubberized fabric, there are, in all, three different manufacturing processes going on in parallel, between the preliminary mixing process (No. 5) — consisting of several rollers driven from a common line shaft — and the vulcanizing process:— the manufacture of the tread, the calendering process and the making of the inner tube proper. Apart from the machinery for the manufacturing process, there are steam boilers, compressors to generated compressed air, a pumping station for providing water as well as pumps for water under pressure for vulcanizing and for cooling.

A glance at the number of machines which require individual regulation suffices to show that individual drive alone will meet the requirements. Only the set of rollers, already mentioned (No. 5), can be driven by a common line shaft because these machines are driven more or less in unison. The three succeeding mills (Nos. 7, 10, and 20), which belong to different manufacturing processes are, however, each driven separately.

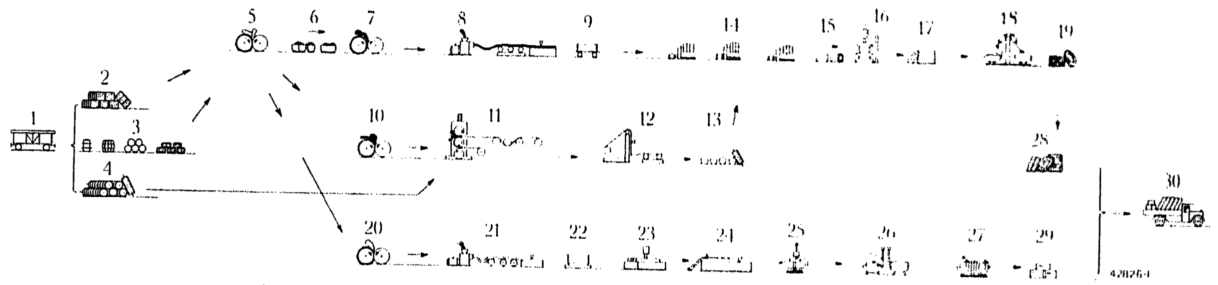


Fig. 1. — Working diagram of the pneumatic tire cover and tube manufactory.

1. Raw material supply.
2. Bales of raw rubber.
3. Store of primary chemical substances.
4. Cord fabric for tires.

Tire-cover manufacture.

5. Mixing mill, 84".
6. Compounders.
7. 60" mixing mill.
8. Extruding machine for tread surfaces.
9. Store of tread surfaces.
10. Warming mill.
11. Calender for fabric gumming.
12. Fabric-cutting machine.
13. Store for rolls of fabric strip.
14. Tire-cover forming machines.
15. Store for finished tire covers.
16. Tire-cover expander.
17. Store for expanded unvulcanized tire covers.
18. Vulcanizing forms.
19. Store for finished vulcanized tire covers and for inspection.

Tire-tube manufacture.

20. Warming mill, 60".
21. Tube machine.
22. Store for half-finished tubes.
23. Valve-hole machine.
24. Skiving machine and putting in of valves.
25. Putting together of open ends.
26. Vulcanizing forms.
27. Inspection and tube store.

Storing and delivering.

28. Store of tire covers packed.
29. Store of tire tubes packed.
30. Delivery by cars.

The motors can be classed in three groups each of which has its own supply system:— the big motors supplied straight from the 3400-V three-phase system, the speed-regulated motors connected to a separate D. C. three-wire system and, finally, the numerous medium and small three-phase motors supplied from the low-voltage 380-V system.

The diagram of Fig. 2 shows the power supply and distribution. For standard requirements, the power comes from Olten-Gösgen power station, through an outdoor station in the grounds of the manufacturing plant and which contains an 8000-kVA transformer. There are three outgoing 3400-V leads from

the switchgear building beside this transformer, two of these going to an electric boiler and one to the motor-distribution plant in the "central station". From here, the big motors are supplied, among them the driving motor of both the D. C. generators and the 380-V motor system and 220-V lighting system through two transformers each of 600 kVA. A part of the lighting plant and some very important manufacturing motors can be fed from the Elektra Baselland power house (150-kVA transformer) through a spare line, in case of trouble on the ordinary supply system.

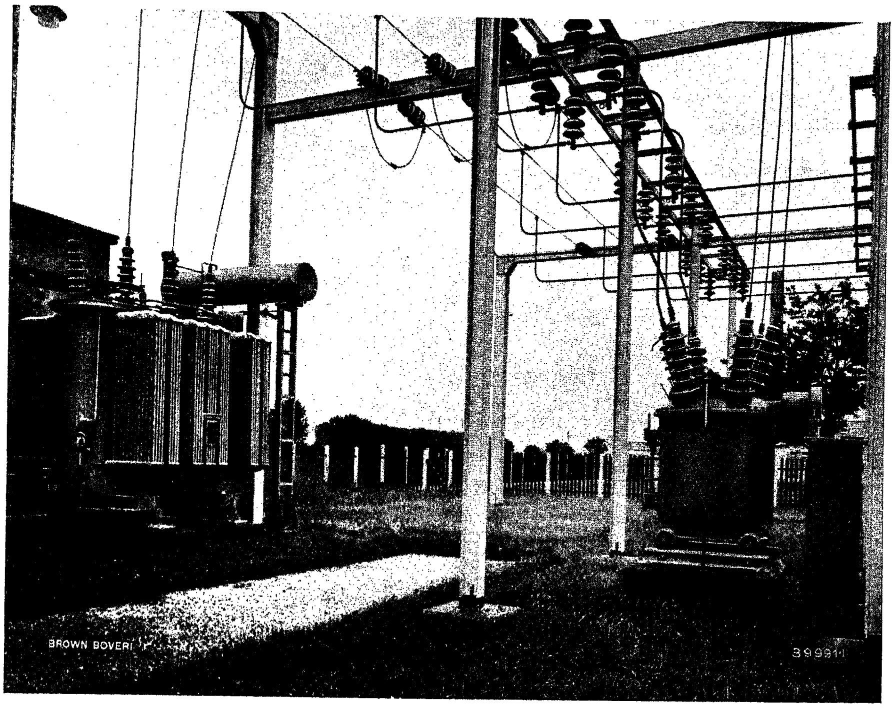


Fig. 3. — Outdoor station.

Fig. 3 shows the outdoor station. The power transmission from the power station is at 50 kV and the voltage is stepped down to 3400 V in an 8000-kVA transformer. To allow the transformer to meet the voltage variations, which occur and also work in

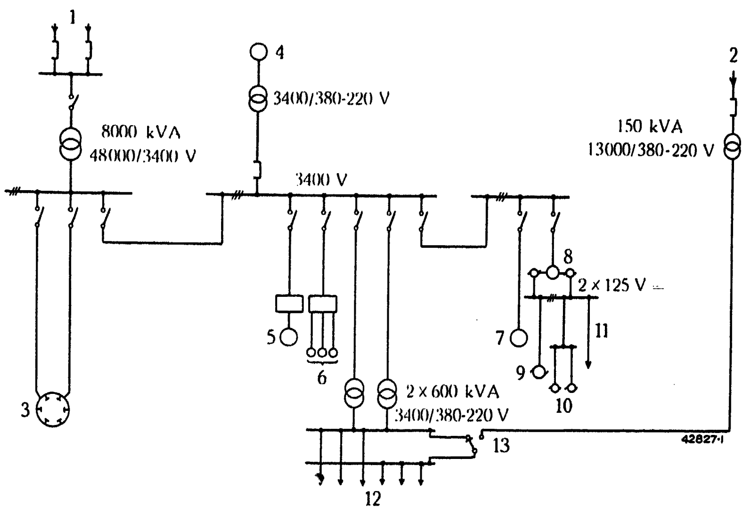


Fig. 2. — General switching diagram.

1. From Olten-Gösgen.
2. From Elektra Baselland.
3. Electric boiler.
4. Pumping station building for ground water.
5. 84" mixing mill.
6. 60" mixing and warming mill.
7. 132-kW compressor.
8. Three-phase direct-current motor generator.
9. Calender.
10. Tube machines.
11. D. C. feeder line (for other variable-speed drives and the excitation of the synchronous motor).
12. Three-phase low-voltage distribution.
13. Emergency-line change-over switch.

parallel with existing units if required, the windings are designed for the following voltage ratios:— 51630—50650 —49450—48330—47130—45940/ 14750—14400—14050 V. The taps of the star-connected high- and low-voltage windings are led to tap-changing switches, which can be operated from the ground level when voltage and current are cut off. The low voltage winding can be changed over to 3512 V, through a man-hole.

The transformer, built for natural cooling, with tubular radiators welded on, was so designed that it could be freighted on the railway in complete state. The oil conservator is carried on special supports and not lodged on the cover, this to make the layout of the leads easier. A Buchholz protective relay can be placed on the connecting pipe between the transformer oil tank and the oil conservator. There is an indicating thermometer with adjustable contact device, placed at one side of the oil tank at the level of the eyes of an observer; it allows of supervising the temperature.

The transformer is connected to the high-voltage line through a three-pole single-tank oil circuit breaker, which is

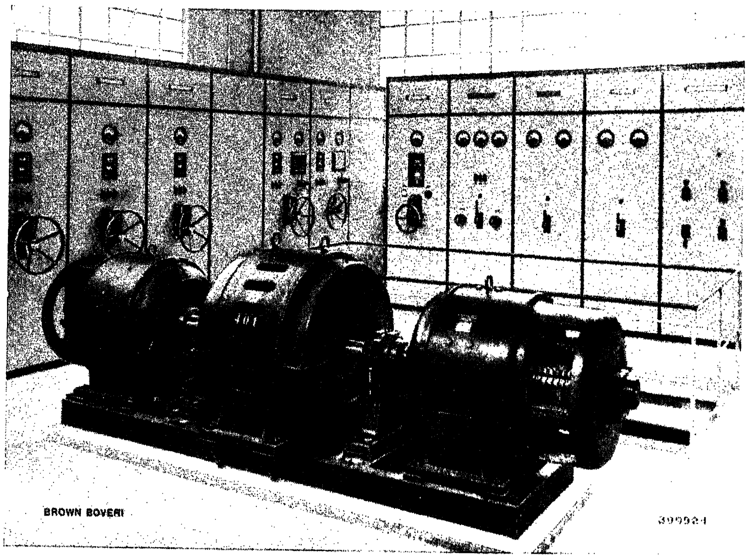


Fig. 4. — Power station.

also of outdoor design. The very heavy short-circuit load which may have to be ruptured at the point of connection was the chief factor determining the choice of circuit breaker. This breaker can clear 500,000 kVA at 50 kV at a very high switching speed. The contacts, designed as wedge shaped cross pieces and forming part of the light moving part, allow of switching in on currents up to 42,000 A peak value. The tank is cylindrical while the bottom and cover are domed-shaped so that pressure stresses occurring when short-circuits are ruptured can be safely withstood. The flanged-on condenser-type bushings with porcelain sleeves are equipped with current transformers to allow of connecting over-current or distance relays.

The oil circuit-breaker has a power-storage drive, the power required for switching being stored up in a spiral spring, which is either wound up by a small winding-up motor controlled from the operator room or else by a handle. Apart from the power-storage drive, the driving stand holds two secondary over-current time relays with mechanical operation of the breaker tripping device.

Fig. 4 gives a view of the power plant. A switchboard of 17 panels, composed of two parts at right angles to each other, contains all the switching apparatus and control instruments required for the motor and light distribution. All the high- and low-voltage breakers have manual drive, as no remote control is required here.

The three-phase D. C. motor generator set is mounted on the station platform. It is composed of a synchronous motor 330 kW, 3400 V and two D. C. generators each of 150 kW, 125 V, which are connected to a three-wire system 2 × 125 V. This subdivision allows of increasing the regulation range of certain motors, without making them more expensive. The synchronous motor is started up by hand through a starting transformer with only one preliminary step.

Drive of the 84" rubber mixing mills.

The preliminary mixing mill (No. 5, Fig. 2) consists, as said previously, of a set of five mixing mills of 84" roller length all driven from a common line shaft. These mills are driven by a synchronous motor, 440 kW, 600 r. p. m., 3400 V, through a Brown Boveri industrial reduction gear, Type NSW, with double helical teeth and a reduction ratio of 600/100 r. p. m. This reduction gear is coupled to the line shaft (Fig. 5). The motor is of open design with welded housing and it is of very rugged construction because it has to stand up to exceptionally severe shocks caused by braking, on the subject of which more will be said further on. The reduction gear has a forged-iron housing, the pinion being of high-grade chrome-nickel molybdenum steel of great tensile strength and the big gear wheel of a cast-iron body carrying a shrunk-on rim of special steel. Both pinion and shaft of the big gear wheel have free shaft ends in order to allow of utilizing the sides of the teeth which have done no work, so far, by changing round the wheels. This allows of prolonging the useful life of the reduction gear.

There was, of course, no difficulty in building a synchronous motor for the output and speed in question. What made the problem and its solution of special interest was the exceptional demands made on the material as regards starting and braking. Generally speaking, a synchronous motor is characterized by the magnitude of the torque in the different

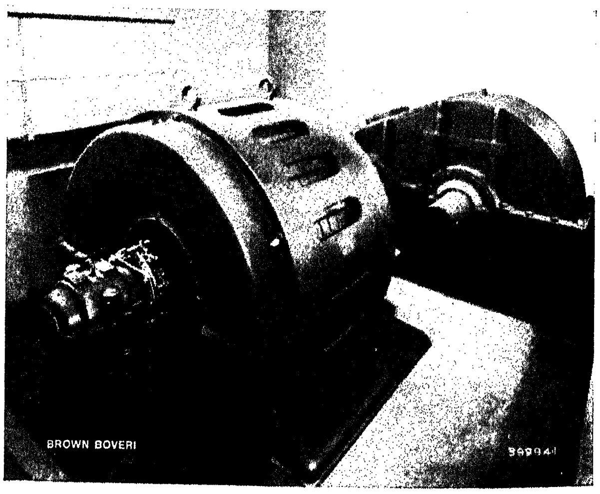


Fig. 5. — Synchronous motor 440 kW with reduction gear, for driving the five 84"-mixing mills.

running phases namely at:— start from standstill, running up, synchronizing, stalling and braking. The specification indicated that, at starting from standstill, the motor had to develop about 80 % of its rated torque, this so that starting could be effected with one or two loaded rolling mills. Under these conditions, however,—and this was imposed by the station delivering power —the motor should not take more than 1650 kVA from the system. At the moment of synchronizing, that is during the passing from starting to synchronous rated speed, the motor had to develop the full torque and had to be able to produce, at least, a 100 % torque overload during service and, thus, overcome the high peaks due to the continuous kneading, squeezing and pull of the rubber worked on. Finally, in the interest of the operator's safety, it was demanded that in case of danger the motor should be designed to be braked down so quickly, that if a workman got caught in the rollers, the motor would only accomplish five revolutions before stopping, this reckoned from the moment the tripping rod was touched; an emergency tripping device being mounted on each rolling mill. This meant producing braking torques which were multiples of the rated service torques.

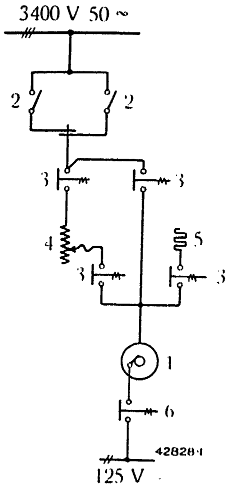


Fig. 6. — Diagram of connections for the operation of the 440-kW synchronous motor.

1. Synchronous motor.
2. Hand switch for reversing sense of rotation.
3. High-voltage contactors.
4. Starting transformer.
5. Braking resistance.
6. Exciter contactor.

Fig. 6 shows the connections of the motor. The latter is started through a single-step starting transformer, which is controlled by high-voltage contactors so that all that is necessary to initiate starting is to depress a push-button. Hand-operated change-over switches are used, only, for changing the sense of rotation, which is an infrequent operation.

Fig. 7 shows the speed, the torque, the current and power-consumption curves during starting. These curves were recorded on the unloaded motor on the test bed. The motor starts from standstill with a torque of about 80 % of the rated one, while only taking about 2·4 times the rated current from the supply system. This was the only way to reconcile Swiss standard conditions with the starting of a big motor by

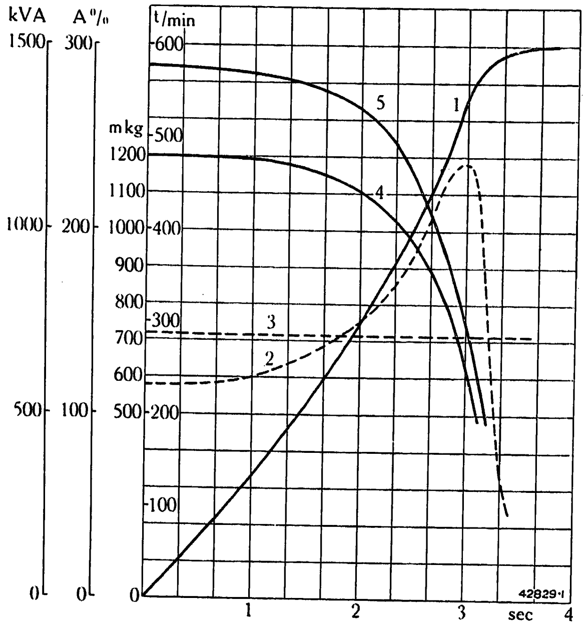


Fig. 7. — Starting of the 440-kW synchronous motor driving the 84" rollers, under a tap voltage on the starting transformer of about 70 %.

1. Speed of motor, in r. p. m.
2. Starting torque in mkg.
3. Rated torque 716 mkg.
4. Current tapped from system in % of rated motor current.
5. Power tapped from system in kVA.

such an exceptional method as that employed here.

The braking process is of especial interest (Figs. 8 and 9). Braking is carried out by the motor being cut off from the power supply, when the emergency switch is actuated, and connected to a braking resistance, its excitation being increased, so that it works as a generator, being thus brought rapidly to a stop. The oscillogram of Fig. 8 shows the time lost from the moment the emergency switch (a) is first actuated until the supply switch opens (b) and

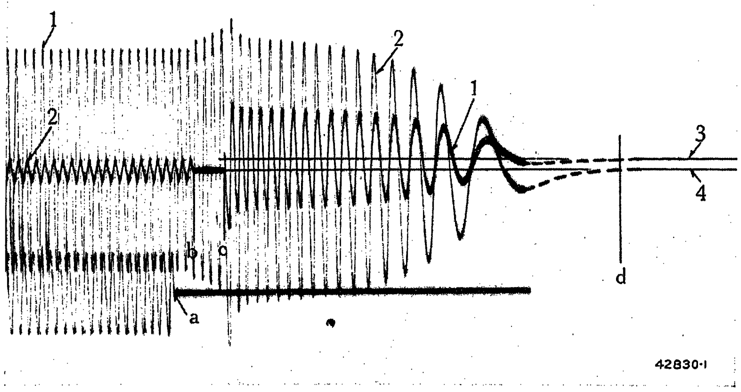


Fig. 8. — Oscillogram of braking process of 440-kW synchronous motor.

Time scale:— 50 cycles = 1 second.
5 „ = 1 revolution.

1. Motor voltage.
2. Motor current.
3. Zero line of voltage.
4. Zero line of current.

a. Emergency switch opens.
b. Line contactor opens.
c. Braking contactor closes.
d. Motor stopped.

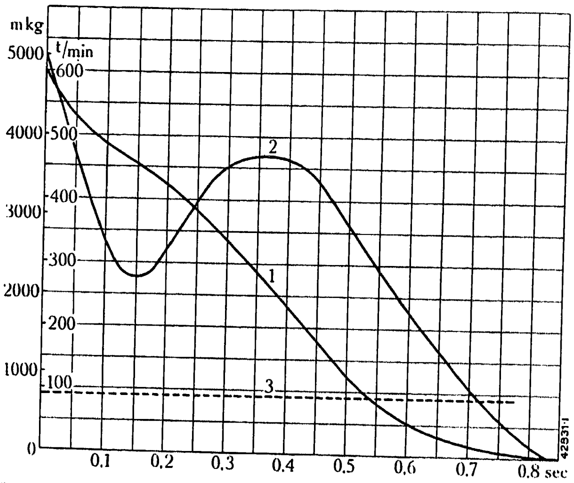


Fig. 9. — Braking the 440-kW synchronous motor driving the 84″ rollers.
1. Motor speed in r. p. m. 2. Braking torque in mkg. 3. Rated motor torque (= 716 mkg).

the braking switch closes (c). Although, as is seen, the contactors respond very quickly, the loss of time is considerable as compared to the requirements of the case, because it must be remembered that when all these operations are completed, the motor is still running at full speed and of the five revolutions allowed for in the specification about 1·2 revolutions are wasted. As the diagram of Fig. 9 shows, however, the braking torque developed is so high that this big and heavy motor is brought to a stop in less than one second effective braking time. With a rated motor torque of 716 mkg the torque at the initiation of braking is 5000 mkg, that is seven times the rated torque. What this considerable torque means will be understood better when the peripheral force corresponding to it is calculated. With a rotor diameter of 1010 mm this 5000-mkg torque corresponds to about 10,000 kg retarding effort on the periphery of the rotor, a figure which will make it clear why, to a spectator, the motor seems to be stopped instantaneously.

The question is often raised whether, from the point of view of the safety of operators, electrical or mechanical braking is the best. The objection that, with electrical braking, it is necessary to consume the kinetic energy stored in the motor rotor, which is bigger than that of the other moving parts of the drive and machine, seems, as a matter of fact, to be founded. This is the reason why, in many plants, when braking is applied, the motor is cut off from the machine by a coupling, which can be loosened and the machine is braked down mechanically, alone. Braking is thus made easier, theoretically. In practice, however, the loss of time and unreliability of the loosening of the coupling have to be taken into account, as well as the fact that mechanical braking is very dependent on the frictional conditions of the brakes. For instance, in a rubber factory where talcum dust reduces the friction of the brake blocks considerably, braking may last longer and be more difficult. Electric braking, on the contrary, is exempt from influences of this nature. The increase of the kinetic energy to be absorbed, due to the rotor of the motor is far more than compensated by the exceptionally strong braking torque and by the great advantage that the braking effect is always the same and brought about by means so simple that a failure can be considered as excluded.

Drive of the three 60″ - mixing and warming mills (Fig. 10).

These machines are driven by a high-voltage squirrel cage motor of 110 kW at about 980 r. p. m., through a reduction gear (Fig. 11). The motors have deep-slot rotors and are connected straight to the supply at starting, they develop a strong starting torque under very moderate starting current. The power input, at switching in, is far below the limit value set by the power-supply station.

In these drives, as well, severe braking conditions in cases of emergency were laid down. From the moment the braking switch is actuated, each motor must be stopped within ten revolutions at the most.

If the higher speed of these motors as compared to the motor of the 84″ rolling mill is taken into consideration, it will be recognized that the braking conditions imposed here are hardly less strenuous than

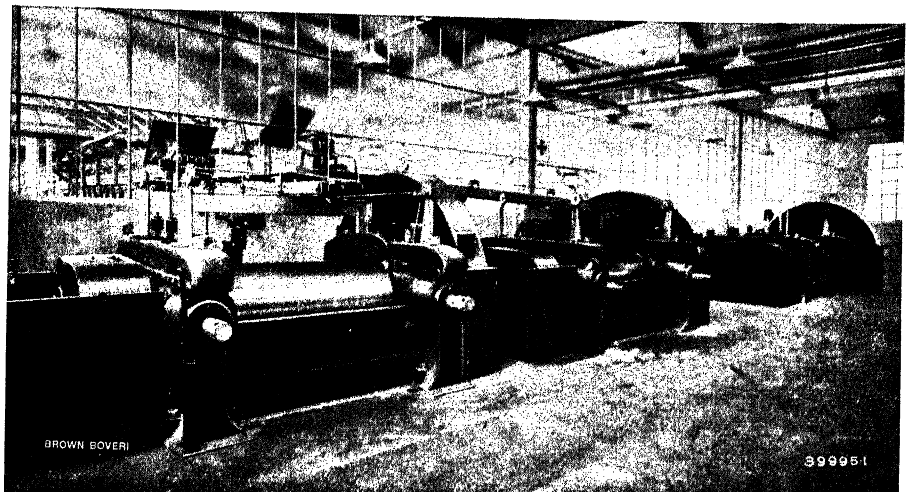


Fig. 10. — Three 60″-mixing and warming mills.

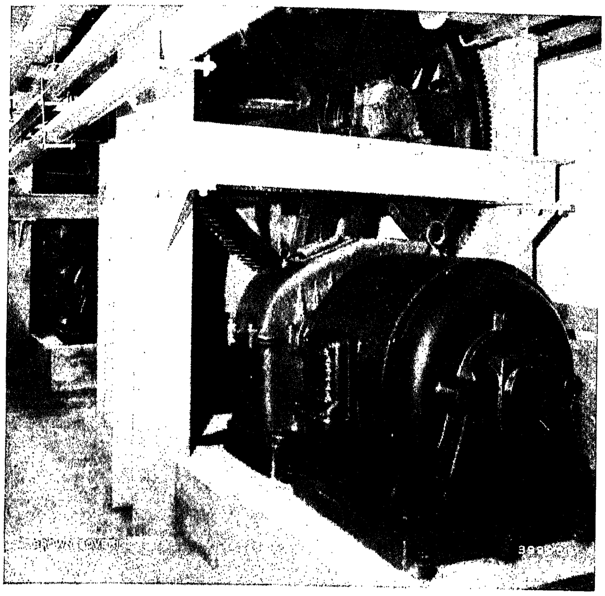


Fig. 11. — Drive of a 60"-mixing and warming mill.
(Three-phase, squirrel-cage, 110-kW motor.)

in the former case. Braking is by counter-current, the motor at full speed being connected to the supply system through interchanged conductors. This does not cause an excessive load peak on the system as, under these conditions, the motor only takes about 15 % more current than at starting and the duration of the braking period is astonishingly short.

The braking process is shown by the oscillograms Fig. 12, recorded on the test bed. In this test the flywheel effect of the motor has been increased by about 25 % by coupling to an auxiliary machine and, over and above this, the test was made at only 88 % of the rated terminal voltage, in order to take into account the most disadvantageous voltage conditions.

At point a, the emergency switch is actuated and this first opens the service contactor and, 0·135 seconds later, closes the braking contactor. During this time lost for the braking proper, the motor revolves about 2·2 times. From the moment the emergency switch is actuated until full stop is reached, at point b, 0·93 seconds elapse, which means that the motor makes about eight revolutions. There are 0·8 s for the braking process proper and 5·8 revolutions. The average braking torque is, here, 200 mkg corresponding to about 182 % of the rated torque. At the full-rated voltage, braking would only have taken about 0·62 seconds corresponding to 4·5 revolutions with an average braking torque of 235 %. Within the A. C. period the motor would only have accomplished 2·2 + 4·5 = 6·7 revolutions. This shows that, even with a bigger flywheel effect, the limit conditions imposed are not reached. The use of this braking system has justified itself as regards the objections first raised against it.

Drive of the reciprocating compressors.

Various machines used in the manufacture require large quantities of compressed air, to provide which two Sulzer reciprocating compressors for 5 kg/cm^2 delivery pressure were put in, one for delivering 1350 m^3/h, the other for 340 m^3/h. The compressors can work independently or together and deliver air to a compressed air container from which the distribution pipe takes off leading to the shops. There is a regulator built into the common suction duct, which maintains constant air pressure.

The bigger of the two compressors it driven by a direct-coupled three-phase synchronous high-voltage motor of 132 kW output, 375 r. p. m. (Fig. 13). The shaft runs in two pedestal bearings, which are carried as well as the motor housing on a common

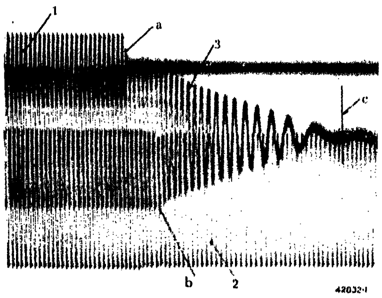


Fig. 12. — Oscillogram of the counter-current braking of a 110-kW motor of the 60"-rolling mills.

Time scale: — 50 cycles = 1 second.
3 „ = 1 revolution.

1. Control current in current circuit of emergency switch.
2. Voltage of system.
3. Voltage at terminals of measurement motor (giving curve of speed of test motor).

a. Emergency switch opens.
b. Counter-current contactor closes.
c. Motor at a stop.

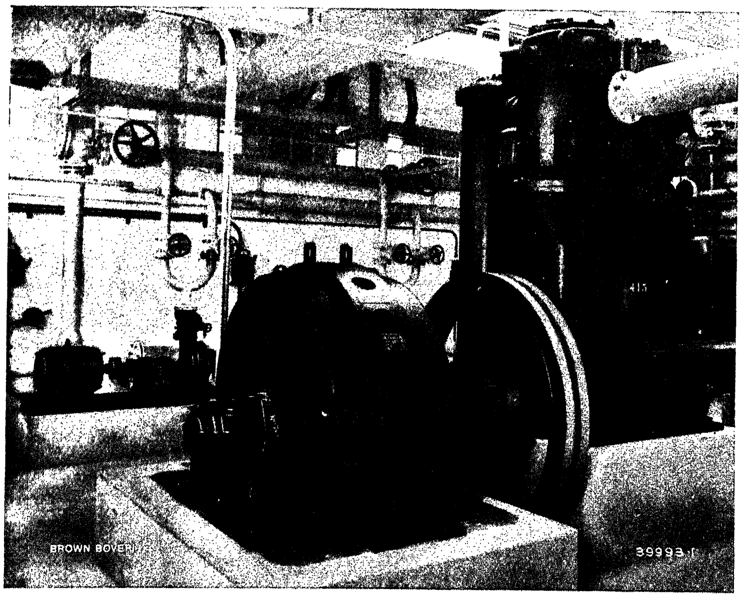


Fig. 13. — Drive of the bigger air compressor by synchronous motor 132 kW, 375 r. p. m.

frame bedplate. The motor of this compressor, excited from the 125-V D. C. system, is built with a starting damping winding and is connected straight to the supply by the simplest of starting operations. Despite the relatively big moments of inertia, it starts up rapidly under a current of about four times the rated current strength. The starting torque attains about 50 % of the rated torque. The high overloading capacity of the motor is a guarantee of service reliability even at the highest torque peaks to be overcome.

The smaller compressor is driven by a squirrel-cage 37-kW motor at 360 r. p. m. supplied from the low-voltage system. It is also directly coupled to the motor in question.

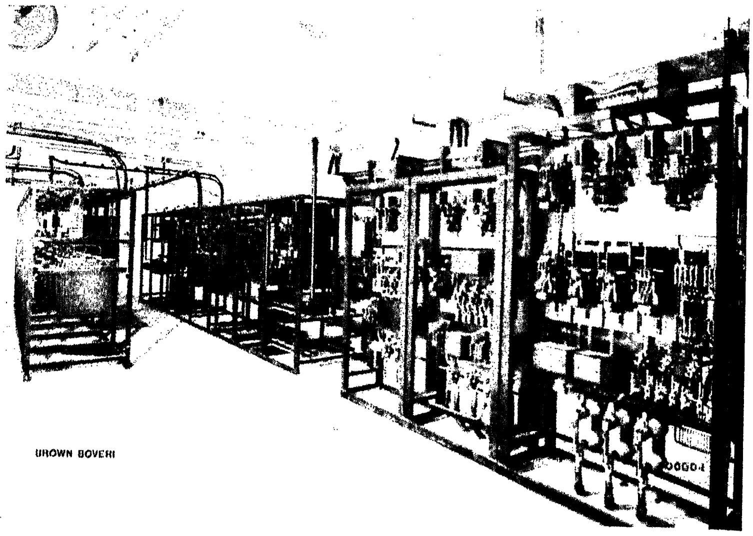


Fig. 15. — Apparatus framework for the three-phase high-voltage and D. C. contactor controls.

D. C. regulated drives.

Calenders, tube machines, bias cutters and gum-dip machines which work at variable speeds are driven by D. C. motors and supplied from the motor-generator set mentioned before. Simplicity in operation was the chief aim in designing these drives. All controls are, therefore, built for contactor- and push-button operation, wherever feasible.

The *three-roller calender* is driven by a D. C. motor which can be connected, as desired, either to the 125 or 250-V system. The output of this motor is respectively 55 kW with a range of speed regulation between 225 and 450 r. p. m. (125 V) and 110 kW with a range of speed regulation between 450 and 900 r. p. m. (250 V). The motor is mounted in the basement under the calender and drives the calender from below through a multiple reduction gear (Fig. 14).

The calender is controlled by a push-button station with seven buttons. Two of these control the choice of the two service voltages and thus the range of speed variation; the voltage chosen is made known during the whole period of service by a lamp. By depressing one of the two buttons, the motor runs up to the speed corresponding to the speed range in question, which is dictated by the regulator, and this in the "forward" sense. Automatically operated starting contactors carry out the switching operations on the starting rheostats, as is usual in such cases, without further intervention of the operator. As the speed regulator does not require to be adjusted, the starting operation is simplified. The same speed is always readjusted to, despite repeated starting operations, this unless an intentional alteration is made. A "reverse" push-button allows of reverse running of the motor, if so desired. In this case, as only low speeds are called for, the motor is solely connected up to 125 V. An "inching" push-button allows of going on rotating the calender rollers step by step, but at the lowest speed. When the "stop" impulse is given, the motor is braked down by being made to work as a generator and comes to a stop within a few seconds. There is an emergency switch actuated by the safety rod, which allows of stopping the machine in case of danger. In this case, reinforced generative braking is initiated, which practically stops motor and calender instantaneously.

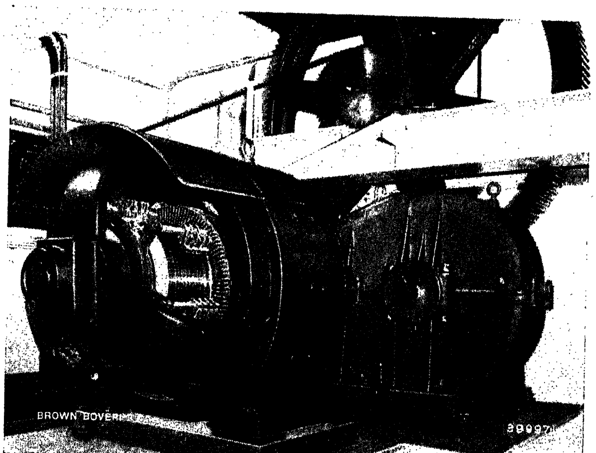


Fig. 14. — Drive of the rubber calender by D. C. variable speed motor 55—110 kW, 225—900 r. p. m.

Of the two *tube machines*, the bigger (8″) is driven by a motor 18·5—37—74 kW supplied from the three-phase system and running at 250—500—1000 r. p. m., the smaller machine (6″) is driven by a motor 37—54 kW at 400—1200 r. p. m. These motors have also got contactor control but only for drive in one sense of rotation. Generative braking also allows of sudden stopping at any moment, in this case as well.

The control apparatus of all remote-controlled drives are lodged in a single switchgear chamber in the basement (Fig. 15). The two frames in the background contain the high-voltage oil-immersed contactors and the other control apparatus for the three-phase motors of the rolling mills; the frame in

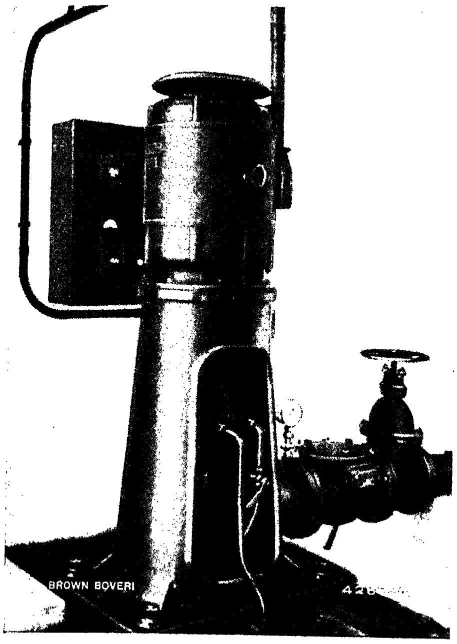


Fig. 16. — Ground-water pumping station.

the foreground contains the D. C. contactor controls for the motors of the calender and tube machines. The removal from the actual working rooms to the basement of this rather big apparatus, proved a very happy solution. Further the frames can be open as they are in a closed-off chamber, this facilitates supervision as the apparatus is easy to get at.

Contrary to this layout all motors and apparatus of the *bias cutter* form a whole with the machine in question. The latter is driven, in all, by three small D. C. variable-speed motors and one small three-phase constant-speed motor. The same design is used for the *gum-dip machine,* which has only one small D. C. variable-speed motor and simple contactor control drive.

Ground-water pumping station.

The water requirements of the plant are covered by a separate ground-water pumping station at a certain distance from the main plant. This pumping station contains a Sulzer shaft-type pump driven by a squirrel-cage, 24-kW motor (Fig. 16). As the pump is controlled from the main plant some auxiliary devices were necessary in order to meet all the service conditions which might arise.

A *hand-control switch* allows of switching in and out the motor contactor in the pumping station, from the main plant. If the pump does not begin to deliver water within a few seconds, after switching in, a drop disc-relay, controlled by a contact connected to the non-return valve, is tripped in the main plant and this calls attention to the trouble. The same thing happens when delivery of water stops during working. The operator can then try to get the pump to work properly by several successive closings of the switch. If this is unsuccessful, the cause of the trouble must be ascertained and the fault remedied. Switching out as a result of overloading in also signalled back to the main plant in the same way.

The control is so designed that it can easily be made over for automatic service and control by time relays or a switch the operation of which depends on the water level. Measures have also been taken to allow of the subsequent putting in of a heating device. All control circuits are operated at 40 V only on account of the danger due to damp. A portable hand lamp can also be connected to this line.

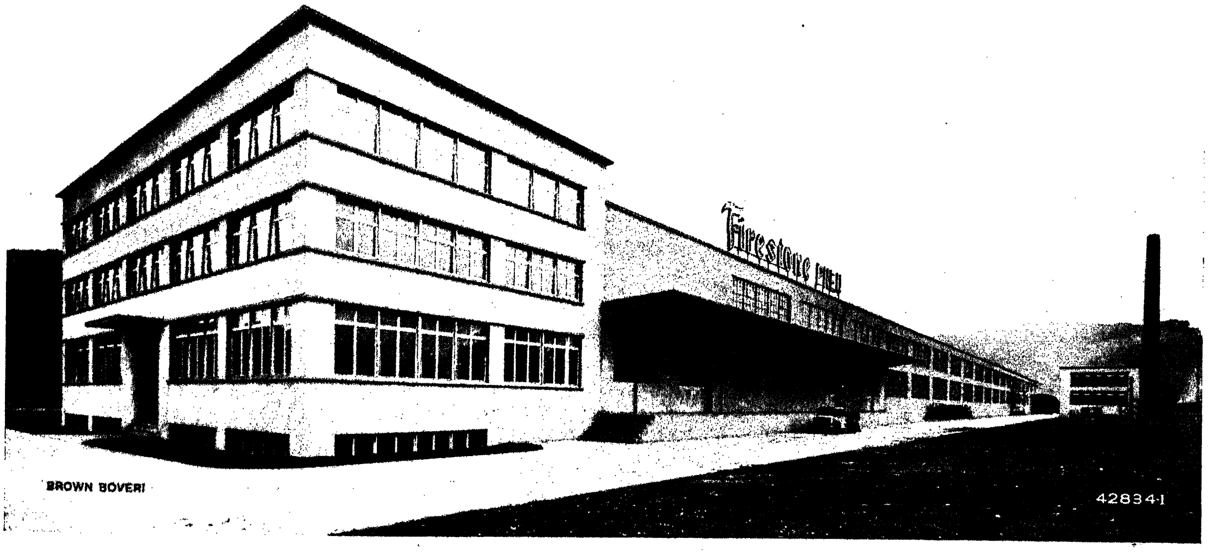


Fig. 17. — General view of the pneumatic tire manufactory.

The electric plant described has shown its efficacity in very severe day-and-night service. There have been no cases of serious trouble. The ease and reliability of all operations are highly esteemed by the supervising engineers and the operating shifts.

(MS 511) S. Hopferwieser. (Mo.)

NOTES.

Drive of ring spinning frames and doubling frames by means of fan-cooled squirrel-cage motors mounted on the headstock.

Decimal index 621.34 : 677.052.3.

THE great importance attached to electric individual drive for ring spinning frames is due to its allowing a very considerable improvement in the manufacturing process and one which is hardly to be equalled by any other machine used in spinning; this quite apart from the well-known advantages of individual drive as compared to line-shaft drive. For this reason, the problem of the individual drive of ring spinning frames has always been an interesting subject and has been more or less perfectly solved by a variety of applications. We give here only two striking examples, which represent the two designs most commonly used in practice namely:— variable speed drive by commutator motor with a spinning regulator and drive by squirrel-cage motor on the headstock by belt and step pulleys. An ideal solution is the variable-speed drive by commutator motor with spinning regulator developed by Brown Boveri.

It allows of maintaining constant thread tension during the spinning process, by means of smooth speed regulation and it produces better yarn while increasing the production of the machine.[1] For this reason, the shunt spinning motor is used increasingly in cotton spinning mills as well as in woollen and bast-fibre spinning mills. In specific cases, however, the question may arise as to whether it is really profitable to chose this drive, which gives a maximum of output of spinning machines. In many cases, satisfactory results are attained without any adjustment of speed or with an adjustment within a narrow range, only; this is the case, for example, in cotton-spinning mills producing only coarse yarn which is always of the same count. There are, also, other enterprises which may be forced to go without the advantages of variable-speed spinning in order to keep down the first costs of their plant. In cases like this, squirrel-cage motors offer a solution; these, however, must not be employed for direct drive of the machine shaft, because the start would be too abrupt and there would be hardly any advantages at all as compared to line-shaft drive. It is of primary importance that these simple drives fulfil the following chief requirements:— smooth starting, quiet and uniform power transmission, biggest production possible and easy attendance. Experience has shown that a specially suitable arrangement is the mounting of the motor on the headstock of the driven machine and belt drive over step pulleys, with the aid of a jockey pulley (Fig. 1). A two-step-pulley of double width is mounted on the motor and on the machine shaft. The diameters are so chosen that the speed (r. p. m.) difference is about 12 %. The cop bottom is spun at the lower speed and the upper part of the cop at the higher one. This allows of reducing the number of thread breaks to a relatively low figure and, at the same time, of increasing the spinning speed as compared to line-shaft transmission and, therewith, the production. It is also possible to spin continuously at the lower speed so that there are two working speeds available. By interchanging the motor step-pulley the speed can be still further modified. In the place of different step pulleys, it is possible to use a specially-designed hub to which step-pulley rims of various diameters can be bolted.

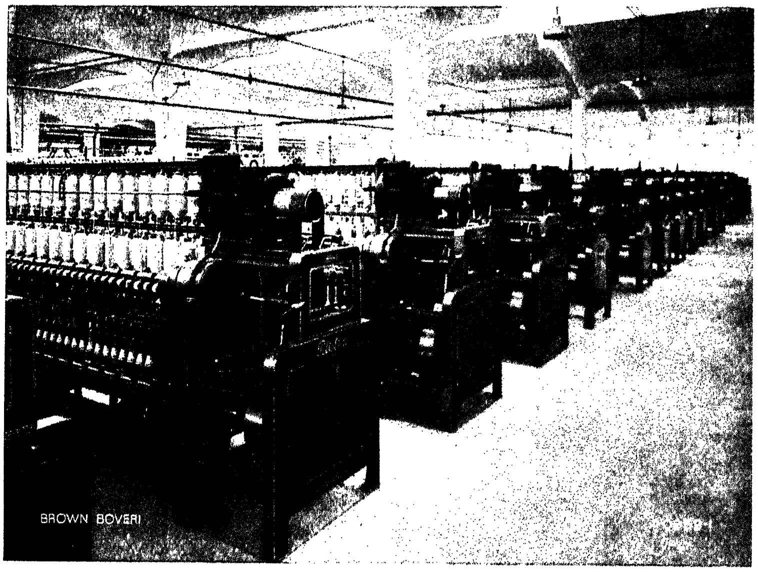


Fig. 1. — Step-pulley drive of ring spinning frames for cotton, by totally-enclosed, fan-cooled squirrel-cage motors.

The motor-protection switch with thermal releases is built on to the motor and can, if so desired, be equipped with a low-volt release. It connects the motor straight to the supply system. Despite this and thanks to the jockey pulley, starting is smooth; there are few thread breaks and the machine is in no way stressed. If it is desired that the motor should start under no load or if the conditions imposed by the power supply company make a star-delta starter necessary, a belt-loosening device can be supplied. This allows of the motor starting under no load, with jockey pulley raised, and being either connected straight to the power supply system or through a star-delta starter; the machine driven is then started by gradual tightening of the belt. There is a hand-operated crank which allows of displacing the belt from the outer to the inner step, once the bottom of the cop has been completely wound, so as to increase the speed. In this operation the lengths of belt coming on to the pulleys are guided simultaneously on to the pulleys of the machine and of the motor respectively, by the two belt forks.

[1] See special Brown Boveri publication on this subject.

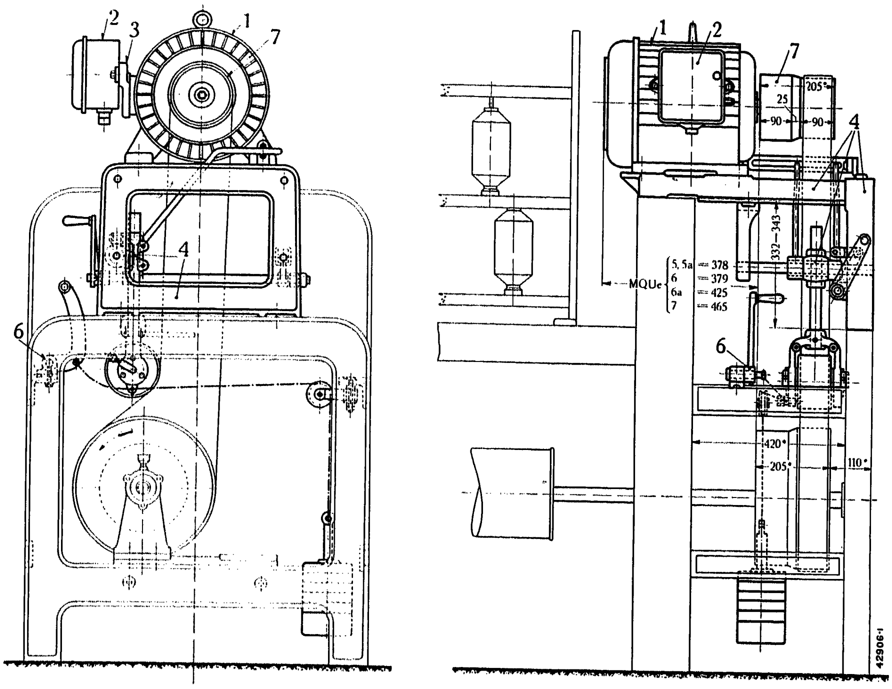


Fig. 2. — Electric equipment with step-pulley drive for ring spinning frames and doubling frames.

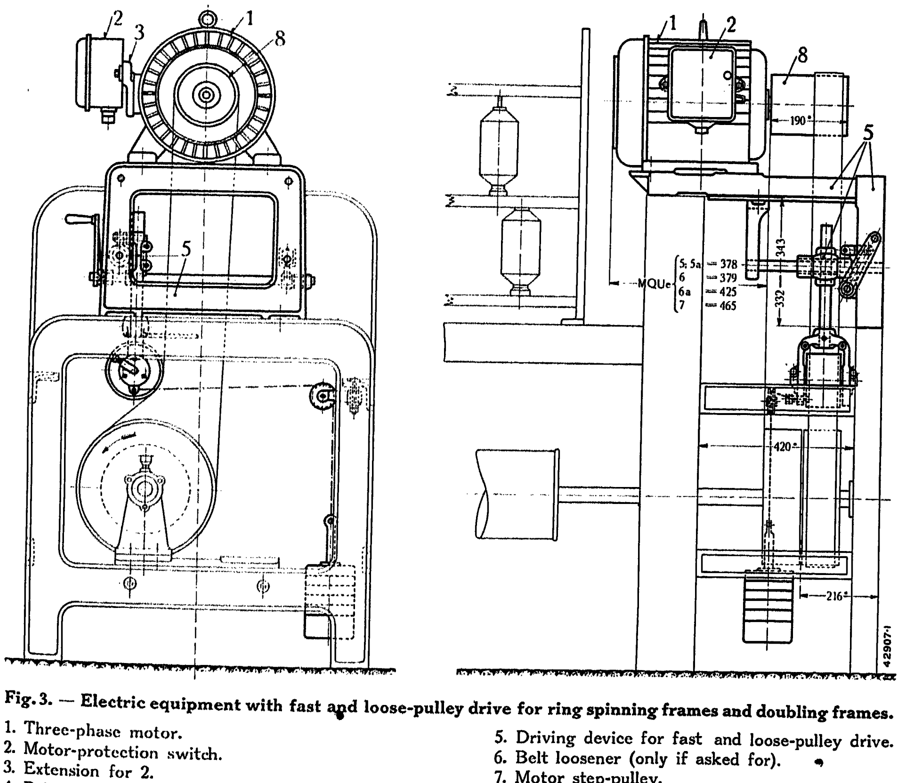


Fig. 3. — Electric equipment with fast and loose-pulley drive for ring spinning frames and doubling frames.

1. Three-phase motor.
2. Motor-protection switch.
3. Extension for 2.
4. Driving device for step-pulley drive.
5. Driving device for fast and loose-pulley drive.
6. Belt loosener (only if asked for).
7. Motor step-pulley.
8. Motor belt-pulley (double width).

(The thick-lined parts belong to the individual drive equipment.)

The driving equipment described can be put on new as well as on old machines formerly driven by line shafting. It takes up little space and, usually, the ordinary spacing between the main shield and the fender suffices. The necessary alterations are very small ones. If no step pulleys are desired and if the fast and loose pulleys on the machine shaft are retained, the rotor of the motor is equipped with a cylindrical pulley of double width, in which case, of course, there is only one working speed. In this case the motor always starts up under no load and this can be done by straight connection to the supply or through a star-delta starter.

It is impossible for dust to penetrate into the totally-enclosed fan-cooled motors. Attendance is limited to occasional inspection of the grease-lubricated ball bearings. As four-pole high-speed motors designed with multi-slot rotors are used and as the jockey pulley also has ball bearings, these drives are economical as regards current consumption.

Step-pulley drive does not fulfil the technical requirements of spinning as completely as variable-speed drive by shunt commutator motors with spinning regulator, mentioned at the beginning of this article. Apart from the reduced thread tension during a short period due to lower speed when forming the cop bottom, there can be no compensation of thread tension during spinning. Therefore, such manifold and far-reaching improvements of the spinning process as are attained when spinning with variable speed cannot be expected here. The step-pulley drive, however, fulfils the object for which it is built and does not only satisfy the simple technical requirements of satisfactory spinning as defined at the beginning of this article, but also allows of greater production; it is characterized by economic operation, easy attendance, small space requirements and great reliability, all qualities which are due to its practical and simple design.

(MS 506) *H. Wildhaber. (Mo.)*

The transformed four-axle single-phase motor coaches of the Berner Alpenbahn-Gesellschaft.

Decimal index 621.335.4 (494).

AMONG the first motor vehicles put into service about the year 1910 by the Berner Alpenbahn-Gesellschaft, there were three passenger motor coaches. At that period, it was still very general practice to split up the electric equipment into two halves which were independent of one another. Thus, for the motor coaches in question, the design was with two groups each with a power transformer, two driving motors and the requisite switchgear.

To begin with, as the coaches were to run on the Spiez-Frutigen line section with gradients of about 1·5 %, it was judged sufficient to put in one half of the electric equipment only, namely:— 1 transformer, 2 motors and the necessary switchgear for these.

The two single-phase series motors were lodged in one bogie, being suspended as in a tramway and having a simple reduction gear. With a coach tare of about 57·6 t, the pressure on each driving axle was 16 t while that on each axle of the runner-wheel bogie was 12·8 t. This led to an adhesion weight of the coach unloaded of 32 t.

When travelling at 45 km/h, the total one-hour output of both driving motors was 450 H. P. The highest admissible speed was fixed at 70 km/h.

Since the period when these coaches started running, service requirements as regards load to be carried and travelling speed have increased considerably. Instead of building in the second driving-machinery and switchgear group, already mentioned, in order to allow the coach to meet the new service requirements (that is to say by adding another transformer and two driving motors and apparatus), the railway management decided that it was preferable to replace the electric equipment entirely, without regard to the old equipment.

The first of the three transformed coaches was put into service in April 1936. All four axles are driven by axle-type motors which are all supplied by the same transformer. The new driving motors are self cooled instead of having a separate motor-driven fan as in the old equipment. Despite this, it was found possible to bring down the weight of the new motors by a considerable amount. Thus, while the two old motors, giving a total of 450 H.P. one-hour rating at a speed of about 45 km/h, weighed 7900 kg together, the total weight of the 4 new motors per coach giving a total of 800 H.P. one-hour rating at 52 km/h, is only about 5200 kg. In other words, there is about 77 % increase in output and about 34 % decrease in weight, a difference which is still more marked if the weight of the fan equipment is added to that of the old motors.

The new transformer is calculated for a continuous output of 490 kVA. It requires little headroom and can be lodged under the floor of the coach. The flow of cooling air set up when the coach is running streams along the cooling pockets which are located on both the longitudinal sides of the transformer. The 15,000-V condenser-type lead is laid, without any bend, from the transformer to the bushing insulator on the roof of the coach. On the low-voltage side, the transformer has 6 taps which allow of adjusting 11 starting and travelling steps with the help of a divider (balancer) coil, which is also lodged in the transformer tank. The saving in weight attained, for the transformer, as compared to the old equipment, is shown in the Table, page 95.

The oil circuit breaker on the old coach is replaced by a simple horn-type fuse on the roof with earthing bow, of the type Brown Boveri has used successfully for light single-phase motor coaches, further the lightning arrestor with earthing switch is done away with.

The electro-pneumatic contactors used for the controls are lodged under the coach floor and close to the transformer. Beside the main controllers in the drivers cabs, there are control switchboxes equipped with toggle switches, 36 V. for the control pilot current, compressor, lighting and electric heating. The control switchbox is mechanically interlocked with the main controller and can be locked by means of a small key when the switches are in the dead position. The supervising lids of the transformer and line apparatus can only be opened by means of this key and when the current collector of the coach is lowered.

A modern type of reciprocating compressor of low design takes the place of the old compressor; it is designed to supply 400 litres per minute of air at 8 kg/cm² gauge pressure. There is a reduction gear for a ratio of 1630:275 between the single-phase driving motor, 3·5 kW, and the compressor.

It is of interest to see the effect of the transformation on the total and adhesion weights of the coach.

After the coach had been considerably improved, as regards running qualities and mechanical strength, by lodging swing bolsters in the bogies and by putting in trusses for the coach frame, the available tare for adhesion purposes was 55 t as compared to 57·6 t with 32 t adhesion weight of the old coach. At the same time, the one-hour load rating was increased from 450 H. P. to 800 H. P.

If the original project of simply doubling the former equipment had been pursued, the tare of the coach would have risen to about 75 t.

It is of interest to compare the output and weight data for the old and transformed coaches, as this com-

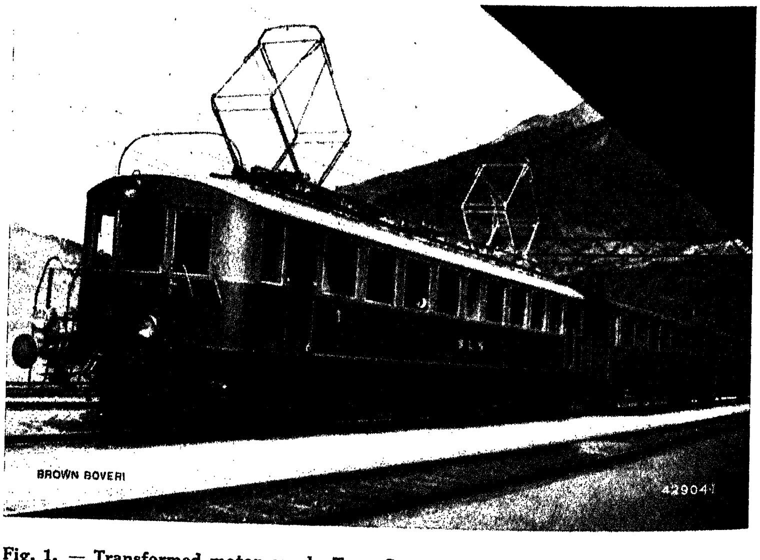


Fig. 1. — Transformed motor coach, Type Ce 4/4, No. 783 of the Berner Alpenbahn-Gesellschaft, after being put into service again.

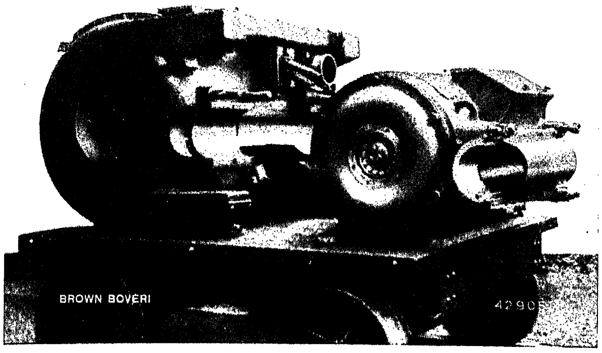


Fig. 2. — Comparative illustration of the driving motors: — on the left, the old separately-cooled motor, on the right, the new self-cooling driving motor.

parison gives proof positive of the progress accomplished in recent years in the design and construction of single-phase vehicles. The most important figures are given in the following Table.

	Ce 2/4 coach before transformation	Ce 4/4 coach after transformation	Increase + Decrease − abt. %
One-hour output rating	2×225 = 450 H.P.	4×200 = 800 H.P.	+ 77
One-hour tractive effort at wheel tread	2500 kg at 45 km/h	4000 kg at 52·5 km/h	+ 60
Starting tractive effort	3700 kg	abt. 8000 kg	+ 116
Total weight of driving motors	7900 kg	5200 kg	− 34
Transformer weight	4365 kg	4000 kg	− 8·3
Tare	57·6 t	55 t	− 4·5
Adhesion weight	32 t	55 t	+ 72
Diameter of driving wheels	1100 mm	1100 mm	—
Reduction gear ratio	1 : 3·45	1 : 5·6	—

After the first coach was completed, some trial runs with loads were carried out on the Spiez-Brig section of the Berne-Lötschberg-Simplon Railway. Of the total train weight involved, 55 t were for the motor coach and 80 t for the two four axle AB_4 trailer coaches. On the 2·7 ‰ gradient, the speed was about 62 km/h and it rose to 80 and 90 km/h in the Lötschberg tunnel. A maximum speed of 90 km/h was fixed by the railway authorities because of the exceptionally smooth running of the coach. Apart from the perfect behaviour of the electric equipment, mention should be made of the smooth running of the coach on this line section which has numerous curves, this is due to the good influence exercised by the swing bolsters which were put in the bogies.

The rolling material of the Berner Alpenbahn-Gesellschaft which was enlarged by the recent addition of light motor coaches is now still further increased by the transformed motor coaches described here. The railway company built in the electric equipment themselves. Brown Boveri delivered the transformers, six driving motors, the compressors and a part of the apparatus for these coaches.

(MS 523) *W. Lüthi. (Mo.)*

On the electrification of the Rigi Railway.

Decimal index 625.35 (494).

THE first rack railway in Europa, the Rigi Railway, between Vitznau on the Lake of Lucerne and the top of the Rigi, opened in 1871, will be electrified in the autumn of the present year. The necessary transformation, which will bring the railway into line with modern requirements, will entail the acquisition of light and comfortable motor coaches with 72 seats each. These will shorten the trip considerably by a corresponding increase in speed and this means, of course, that the carrying capacity of the railway is increased. The economic running conditions of the railway will be considerably improved as fewer employees will be required, on account of the former preliminary work for the starting up of steam locomotives being now done away with, because there is less outlay for the supervision of electric vehicles as compared to steam locomotives and, also, because one-man control suffices on the motor coaches. For the time being, the railway company has ordered three motor coaches. When peak traffic conditions occur, a part of the existing steam locomotives will be used and these are, therefore, to be considered as stand-by units, for the time being.

The electric equipment of the motor coaches will be built by Brown, Boveri & Co., Ltd., Baden, while the mechanical part and coachwork will be delivered by the Swiss Locomotive and Machine Works, Winterthur.

The chief characteristics of the railway are:—

Length of railway	6857 m
Double tracked	1892 m
Altitude of Vitznau station	440 m
Altitude of Rigi-Kulm station	1751 m
Gauge	1·435 m
Radius of sharpest curve on the main line	80 m
Rack system	Riggenbach
Steepest gradient	25 % (exceptionally 26·5 %)
Average gradient	19·1 %
Electric current system	D. C. 1500 V
Heaviest weight of train (motor coach with coach in front, both with load)	32 t
Highest running speed on up-gradient	18 km/h
Highest running speed on down-gradient	12 km/h.

Fig. 1 gives the principle dimensions and general design of the 16-t motor coach. The two driving motors, each of 165 kW one-hour rating at 1350/2 V terminal voltage and a corresponding running speed of about 14·7 km/h, are lodged between the running axles of the driving bogie on the up-grade end of the coach. The other bogie only serves as runner bogie. Each motor works through a double reduction gear on a driving gear wheel. The layout of the gearing is on the same principle as that built for the first time by Brown Boveri in the rack motor coaches of the Sassi-Superga Railway[1]. There is a cam controller in each driver's cab with a main drum to start the motors and regulate them by resistance braking on the down grade, and a change-over and braking drum. The remaining apparatus of the main current circuit, namely the current collector of pantograph type, a disconnecting switch, an automatic circuit breaker, a Resorbit lightning arrestor, as well as the starting and braking resistances are lodged on the roof of the coach. As secondary circuits, only the interior lighting and the heating of the coach are supplied from

[1] The Brown Boveri Review, year 1935, No. 9, page 178.

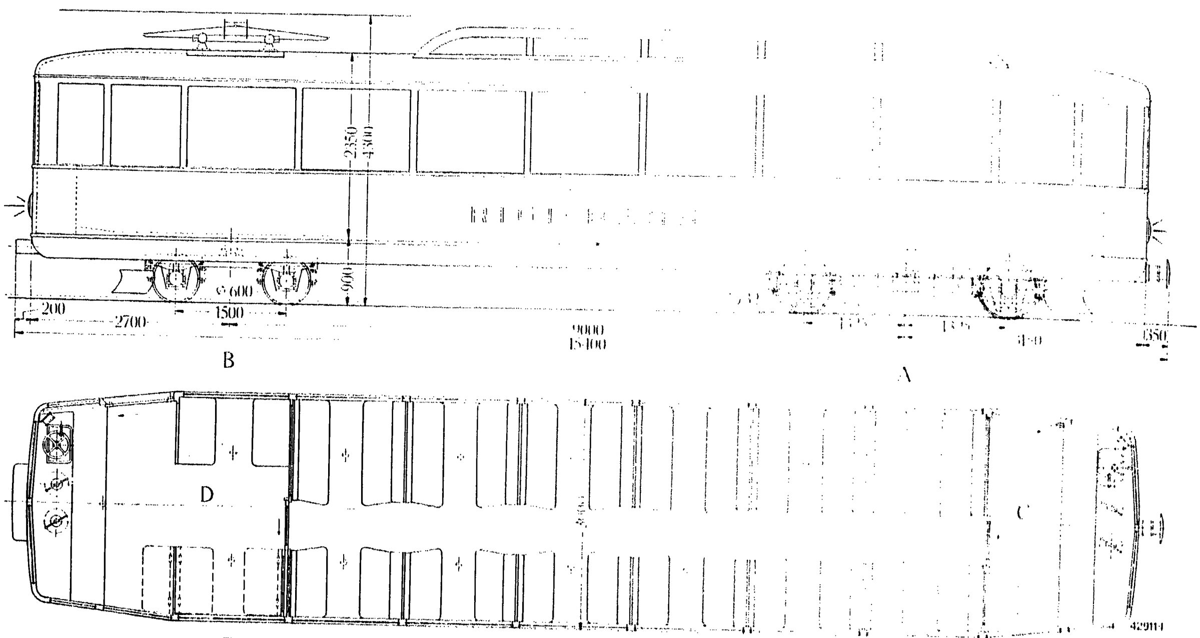


Fig. 1. — Drawing showing the type of motor-coach to be used on the Rigi Railway.
A. Driving bogie. B. Runner bogie. C. Driver cab on up-grade end of coach. D. Driver cab on down-grade end of coach, with luggage compartment.

the overhead line, while the service lighting is supplied from a small storage battery.

The braking devices comprise electric resistance braking as service brake on the down grade, two hand brakes independent of one another, actuated by spindle from either driver cab and an automatic over-speed brake. The hand brake working on the brake drum on the driving gear wheel, is provided with a ratchet device. When on the up-grade, the brake is applied and prevents the coach running backwards if current should fail, this through the agency of the ratchet gear. The other hand-operated brake and the over-speed brake operate on a brake drum on the motor. The over-speed brake can only act during down-grade running; in emergencies it is put into action by the safety device for one-man control.

(MS 528) *E. Hugentobler. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2): 621. 34.

IN the year 1899, Brown Boveri delivered a three-phase induction motor, 300 kW, 3200 V, 32 cycles, 160 r. p. m., to the Albbruck paper mill of the Gesellschaft für Holzstoffbereitung, Basle. This motor drove two press pulp grinders. In the year 1911, this motor was equipped with a Brown Boveri phase advancer and in the year 1926, the two press pulp grinders were replaced by a grinder with continuous supply of wood calling for a power input of about 440 kW, which the original motor had to produce. The plant was transformed from 32 to 50 cycles four years later, on which occasion only the stator winding of the motor was replaced. Since that time the motor has been running, without further alteration, at 3400 V, 50 cycles, 245 r. p. m. Within the last four years its load rose to about 640 kW. Despite its respectable age of 37 years, this unit runs in day and night service perfectly and this while delivering over 100 % more load than its standard rating in 1899. As to the phase advancer connected to it, it has run ever since it was put in without requiring any repair whatsoever. The illustration shows the motor in service.

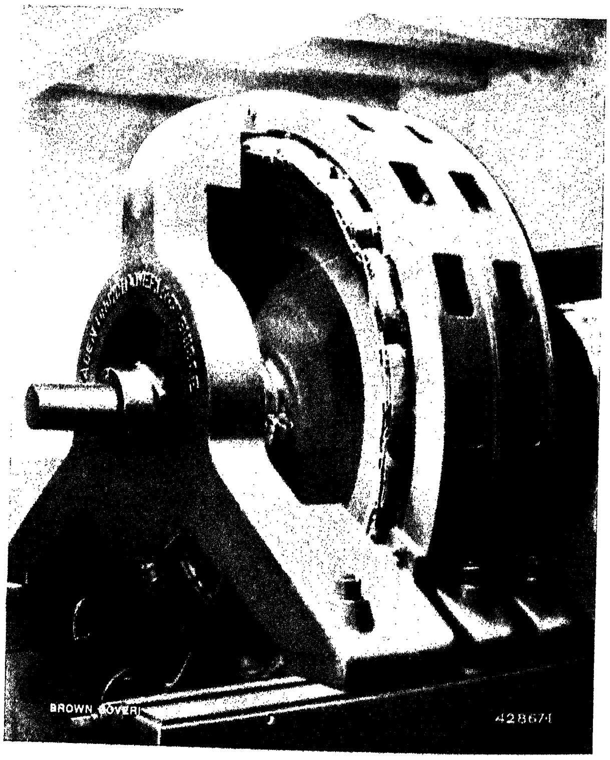


Fig. 1. — Albbruck paper mill of the Gesellschaft für Holzstoffbereitung, Basle. Three-phase induction motor. Works No. 4569, delivered in 1899.

(MS 520) *Prop.*

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THE BROWN BOVERI REVIEW

EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

TRUCK-TIPPING MACHINE OF THE DUTCH RAILWAYS, AT BORN.
Mechanical part by J. Pohlig & Co., of Cologne; electric equipment by Brown, Boveri & Co., Ltd., Baden (Switzerland).

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Printed in Switzerland

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIV APRIL, 1937 No. 4

STABILITY OF THREE-PHASE NETWORKS WITH A DESCRIPTION OF SOME EXPERIMENTAL TESTS CARRIED OUT ON SMALL AND MEDIUM-POWER MACHINES.

Decimal index 621. 316. 13. 016. 35.

I. INTRODUCTION.

A typical example of disturbance of stability is given in Fig. 1. It shows the phenomena accompanying a short circuit occurring on a system and affecting the three phases. A turbo-generator of 2300-kVA output is working in parallel with an extensive network which is represented, diagrammatically, by a big generator. The current consumers on the network are, also, only represented diagrammatically (V in Fig. 1). Suddenly, a short circuit affecting the three phases occurs on a branch of the system. The terminal voltage of the generator, on the right, is caused to drop considerably, thereby; it can no longer produce as much active power as before, while the output of the turbine driving it remains unaltered, at first. This causes the rotor to accelerate and it falls out of step. The angle of the pole wheel, i.e. the phase displacement between the rotor of the generator on the right and the terminal voltage U increases rapidly after a preliminary decrease of short duration. After half a second, it has already attained 80° and, after a little more than one second, 360°. The generator on the right and the remainder of the network operate asynchronously into each other as the behaviour of the pole-wheel angle shows. This causes violent fluctuations of currents and outputs. In the example under consideration, the disturbance comes to a satisfactory end by the generator on the right being pulled into step again by the rest of the network, as soon as the short circuit is eliminated. The pole-wheel angle reaches a stable value after some oscillations and the voltage builds up to its original value.

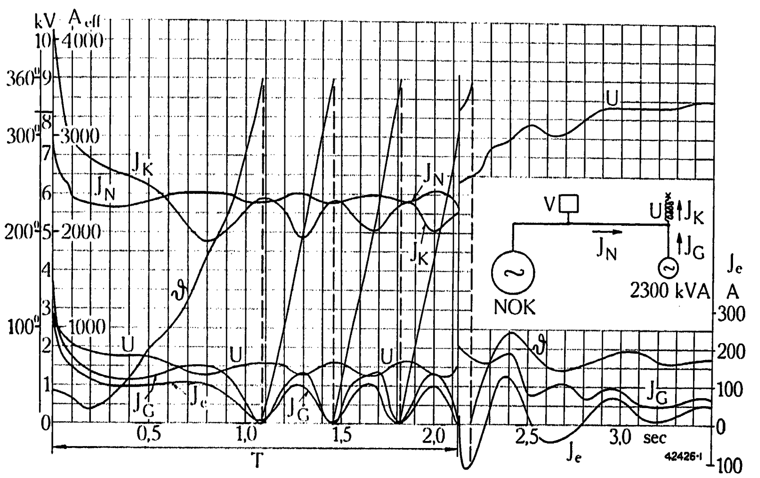

Fig. 1. — Three-pole short circuit on a network system.

J_e. Excitation current of generator, right. U, J_n, J_g, J_K. According to diagram.
ϑ. Angle of pole wheel of generator, right.

However, not every case of trouble has such a desirable ending as this one, namely, that the generators should, finally, pick up and run on normally without intervention on the part of the station staff. It would be exceedingly useful if it were possible to predetermine what the phenomena accompanying a case of disturbance is going to be, for certain given network conditions. In recent years, Brown Boveri has carried out extensive tests to establish the necessary data for calculations of stability and a report on the said experiments is given herewith. In order to make the results of the tests easier to grasp, the most important data taken from the theory of the stability of systems will be, first, summarized.[1]

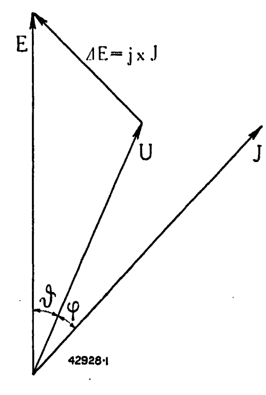

Fig. 2. — Vectorial diagram for a massive cylindrical rotor, omitting the saturation and stator-resistance factors.

E. No-load voltage.
J. Load current.
U. Terminal voltage.
ϑ. Angle of pole wheel.

[1] There exist various publications on the simplest static and dynamic theories of stability, such as those described in the two next chapters. For example: — Ollendorff and Peters "Schwingungsstabilität parallel arbeitender Synchronmaschinen". Wiss. Veröffentl. Siemens-Konzern, Vol. V, No. 1, page 7.

II. STATIC STABILITY.

Machines with cylindrical rotors, if weakly saturated, offer the easiest stability problem. The vector diagram of Fig. 2 is valid for the steady state. The vector E is the no-load voltage, that is the terminal voltage generated by the excitation current set to, when the machine runs under no load. U is the actual terminal voltage for a load current J. The internal voltage drop of the machine Δ E leads by 90° on the current J and is equal to the product of the current and the synchronous reactance x. The ohmic voltage drop in the machine is much smaller than the inductive one and, for the sake of simplicity, is not represented at all in Fig. 2.

It is clearly seen that for a given no-load voltage E, a given terminal voltage U and a given phase displacement (ϑ) between them, the internal voltage drop Δ E is determined both as to magnitude and phase position; therefore, the stator current J is also entirely determined and the same applies to the active output P. The result is given here without the preliminary calculations:—

$$P = \frac{UE}{x} \sin\vartheta \qquad (1)$$

The excitation current and the terminal voltage being constant, if the angle of displacement of the pole wheel varies, the active output changes according to a sine function, which is graphically shown in Fig. 3 (curve 1). When the active output is zero, that is when running under no load the pole-wheel angle is zero; it increases if the active output increases. No bigger output than P_m can occur. If the load exceeds that figure the machine falls out of step. $\vartheta = 90°$ is the *static limit of stability.*

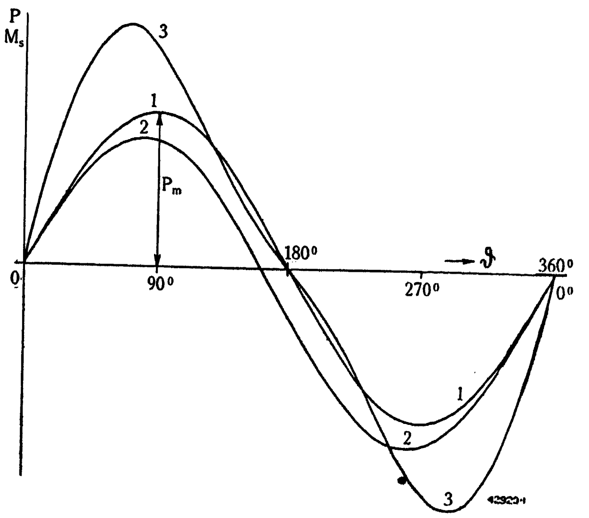

Fig. 3. — Active output of weakly-saturated synchronous machine in function of the pole-wheel angle.

Curve 1. Cylindrical rotor without stator-winding resistance.
Curve 2. Cylindrical rotor with stator-winding resistance.
Curve 3. Machine with salient poles, without stator-winding resistance.

By proper choice of the scale of ordinates, these curves are also a reading of the torque.

The biggest possible output, the *static limit of output,* is

$$P_m = \frac{UE}{x} \qquad (2)$$

It increases as the terminal voltage increases, as the excitation current increases (E proportional to J_e) and as the reactance decreases.

Curve 1 of Fig. 3 is valid for a synchronous machine with constant excitation connected up to an extensive system (U constant). If a transformer or a long line is inserted before the machine so that the voltage across the terminals of the machine does not remain constant, but is constant on the other side of the transformer or at the other end of the line, the constant voltage in question must be substituted for U in equation (1) and the sum of the reactance of the synchronous machine and of the short-circuit reactance of the transformer or the line reactance, respectively, must be substituted in place of x, in other words, the total reactance inserted between the constant internal voltage E and the constant external voltage U must be reckoned with. If it is a case of two synchronous machines of the same order of output, connected to each other through transformers or lines etc., the no-load voltages of the two machines can be substituted for U and E and the total internal and external reactance of the transmission system can be substituted for x; ϑ then represents the phase displacement between the pole wheels of the two machines. In the tests carried out, however, it was, chiefly, the case of one machine connected on an extensive system which was investigated; the other cases can be deduced therefrom.

As said at the beginning of this chapter, the vector diagram of Fig. 2 and curve 1 (Fig. 3) is valid for turbo-machines weakly saturated and leaving the resistance of the stator winding out of account. Curve 2 of Fig. 3 takes the latter into account. This is also a sine curve the axes of which are displaced. For machines with salient poles, the curve is no longer a sine one (curve 3, Fig. 3) and, if saturation is to be taken into consideration as well, the curve becomes still more complicated. All these curves have, however, a feature in common, namely, that for $\vartheta = 0$ the active output is zero; the maximum output is attained somewhere between $\vartheta = 0$ and 180° and the output is again zero in the neighbourhood of 180°; from here to 360° it assumes negative values.

In real transmission systems, the proximity of the static limit of stability is never approached and this for two reasons:— for one reason, the transmission losses would, generally, be far too big in relation to

the power transmitted[1] and for another, there must be a considerable reserve of static stability in order that the transmission system be dynamically stable, as well.

III. TRANSIENT STABILITY ON THE BASIS OF THE STEADY-STATE POWER-ANGLE CURVES.

In the case of sudden or rapid changes of conditions, the danger of the machine falling out of step is greater than under steady conditions or where very slow variations occur. As an example, a synchronous motor, the mechanical load on which is suddenly increased, is first investigated. The curves of Fig. 3 illustrate the active power of the synchronous machine. As, however, the torque is proportional to the active power, the same curves are valid for the torque M_s as well, the so-termed synchronous torque, by altering the scale accordingly. The torque curve is shown again for the synchronous motor in Fig. 4. The load torque of the machine driven by the motor has the initial value M_0. The pole-wheel angle has adjusted itself so that the driving torque of the synchronous motor M_s is equal to the load torque M_0. Now, the load torque (upper figure) is suddenly increased to the value M_1. The new condition of equilibrium now corresponds to the pole-wheel angle ϑ_1. However, on account of the inertia of the pole wheel, this new position of equilibrium is not reached at once. At the first moment after the load increase the pole-wheel angle still holds its original angle ϑ_0 and the driving torque is thus still M_0. As the load torque is greater the pole-wheel is braked down; the lag angle of the pole wheel increases. When the value ϑ_1 is attained, a certain braking work has been expended on the rotor which is represented by the vertically-shaded surface (the momentary resultant torque integrated over the angle passed through).

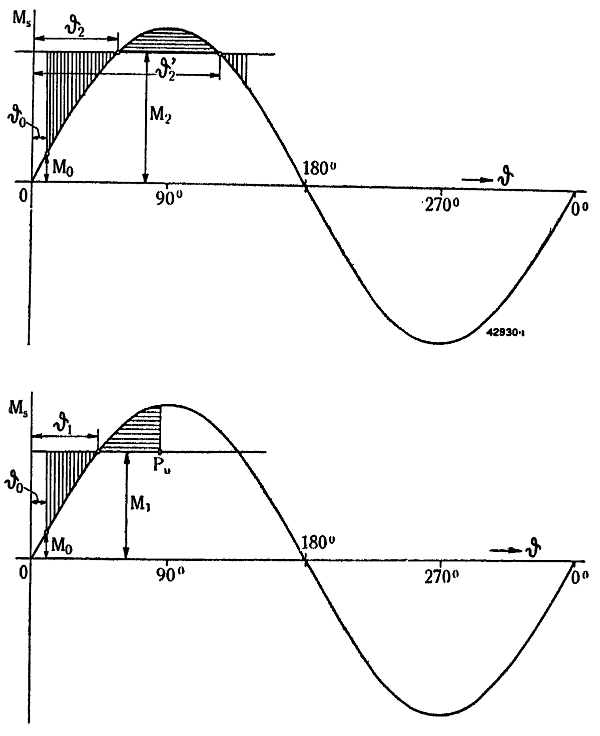

Fig. 4. — Sudden increase in the load of a synchronous motor.

Above: the motor remains in step.
Below: the motor falls out of step.

As the angular speed is now sub-synchronous, the lagging pole-wheel angle gets still bigger, in other words, the pole wheel swings past its new position of equilibrium. The driving torque now becomes predominant and the pole wheel is accelerated. It attains the synchronous angular speed again when the accelerating work, represented by the horizontally-shaded surface is equal to the braking work expended first. The reversal point P_u is determined by the equality of both shaded surfaces. The pole wheel now oscillates about the new position of equilibrium, the oscillations getting weaker as they are gradually damped down.

In the lower Fig. 4, the load torque, starting from the same value M_0, is suddenly increased to M_2 which is greater than M_1. The braking work expended is, now, greater; acceleration can only be carried out up to angle ϑ'_2. As it is less than the braking work expended first, the angular speed at ϑ'_2 is still sub-synchronous, the lagging angle is further increased. Now the load torque predominates again, the rotor is further braked and the machine falls out of step. In this case, the limit of static stability has not been exceeded, but, nevertheless, the motor falls out of step under *sudden* load increase. The limit of dynamic stability lies where the total surface above

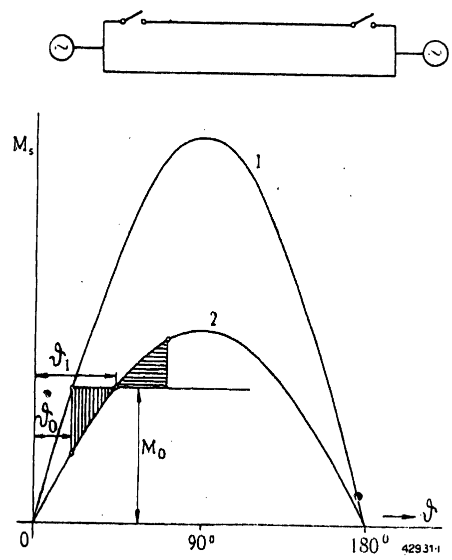

Fig. 5. — Cutting out of a connecting line.

Curve 1. Torque curve before cut out.
Curve 2. Torque curve after cut out.

[1] F. Grieb:— "Betrachtung einiger durch den Zusammenschluss elektrischer Netze bedingter Probleme." Bull. S. E. V., 1930, page 485.

the horizontal line through the new point of equilibrium is exactly of the same area as the surface between the original and new point of equilibrium.

Another important change of condition is the sudden increase of the transmission impedance. This happens when one of two (or several) parallel lines is, suddenly, cut out (Fig. 5). According to equation (1), a lower active output curve corresponds to a bigger transmission reactance x and the same applies to the torque. While the pole-wheel angle was ϑ_0, before the line was cut out, for a load-torque M_0 according to the upper curve of Fig. 5, it must become greater (ϑ_1) after the cut-out is affected, this with constant load torque, because, now, it is the lower curve which is valid. An oscillation through the new position of equilibrium now takes place. The amplitude of the excess oscillation is again determined by the equality of the shaded surfaces. The criterium for a falling-out of step is the same as in the case of a sudden increase in load.

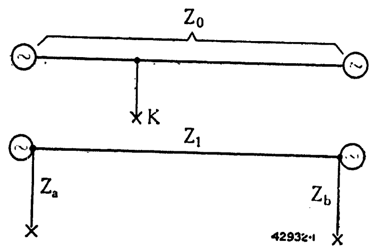

Fig. 6. — Short circuit on a branch of a transmission line and substitution by the so-termed Π connection.

K. Point where short circuit occurs.

The most dangerous change in conditions is the occurrence of a short circuit somewhere on the system between the two machines (Fig. 6). Seen from the terminals of the machines, the transmission line with the short circuit on a branch thereof is equivalent to the so-termed Π connection in Fig. 6 below. The transmission impedance Z_t is, here, bigger than the actual impedance Z_o of the line without short circuit. Further, the load impedance Z_a and Z_b appears on the machine terminals. The mathematical process to determine the Π connection will not be gone into, here. It is easy to understand its qualitative exactitude. When a metallic short circuit occurs on the connecting line, affecting all three phases, it is understood that no load can be transmitted from the beginning to the end of the line. When a short circuit occurs on a branch line, the output which can be transmitted will be smaller than when the system is in sound condition. This is equivalent, however, to an increase in the transmission impedance. Further, power flows from the machines at both ends of the line to the defective short-circuit point which has the same effect as though a load impedance had been inserted on the terminals of each machine (Z_a, Z_b). A short circuit, therefore, has the same effect as though the transmission impedance had been, suddenly, increased and, at the same time, the load of both machines been altered. As the impedances Z_a and Z_b do not absorb active power only, but, usually, far greater amounts of reactive power, the e. m. f. of the machines will be weakened which has a very deleterious effect on the stability.

A special class of disturbances which may endanger dynamic stability are the pole-wheel oscillations caused by the driving machine. Oscillations created by badly-adjusted primary governors will not be gone into here; this is a problem for the turbine builder and only affects the electrical designer indirectly. On the other hand, reciprocating engines (such as Diesel engines or reciprocating compressors) generate pulsating torques which cause pole-wheel oscillations. In this case, care must be devoted to keeping the oscillations as small as possible, above all, the frequency of pulsation of the torque of the reciprocating engine must not come into resonance with the inherent frequency of the synchronous machine coupled to it. Without going further into the calculation of the inherent frequency, it should be pointed out that the rotor of the synchronous machine is a system susceptable to oscillate as it has both mass and oscillation-corrective force. The role of the latter is played by the synchronous torque which always draws the rotor back in the sense towards the point of equilibrium, when it would deviate therefrom.

When rotor oscillations are set up, there are periodic deviations from the synchronous angular speed. This causes an asynchronous torque to be set up. In the case of small slips, this torque is nearly proportional to the slip and (if the ohmic resistance of the stator winding and of the line is not too big) is always so directed to reduce the slip. It, thus, plays the part of a damping influence when oscillations occur.

The asynchronous torque also plays a certain part in the sudden changes of conditions spoken of earlier (Fig. 4 for example) in which the magnitude of oscillation is determined by comparison of the shaded surfaces above and below the M_s curve. As shown elsewhere [1], the steady asynchronous torque must not be reckoned with during transient phenomena. The matter will not be gone into further, but reference is made to the following paragraphs.

IV. DEFICIENCIES OF THE SIMPLE TRANSIENT THEORY.

Up till here, the theory expounded seems really simple and clear. In innumerable articles all kinds of conclusion have been drawn therefrom and a number of special problems treated. All these treatises

[1] "W. Wanger:— Beitrag zur Berechnung der dynamischen Stabilität von Synchronmaschinen" (Bull. S. E. V. 1937, No. 3, page 41).

have, however, very limited value because the theory on which they are founded contains a fundamental error. For the transient stability investigations under consideration, it reckons with the M_s curve which was derived from the steady condition. This curve is correct as long as the excitation current of the synchronous machine remains constant. As is well known, however, the excitation current is influenced by the inductive linkage when rapid fluctuations of the stator current occur. Here, it is indifferent whether the changes are due to short circuits, switchings on the system or rapid changes in the angle of the pole wheel.

In the case of very rapid variations, the flux linkage of the excitation winding (approximately, the field and the induced e. m. f.) remains nearly constant. In this case, the e. m. f. E' must be substituted for the no-load voltage E in the equation (1) and the transient reactance x' for the synchronous reactance x, x' being the reactance lying between U and E'. Technical literature contains indications to this effect. As a matter of fact, however, the pole-wheel never changes so extraordinarily quickly that the induced e. m. f. really remains constant. When, however, no internal voltage of the machine is constant, the method of the comparison of surfaces can no longer be made use of. This is because when the rotor moves from towards the right (compare, for instance to Fig. 4) the M_s curve changes continuously. And how is a surface to be estimated when the limiting curve is constantly changing and there is no way of knowing how it will do so?

The Americans have developed a step-by-step method to get round this problem[1]. For a short interval of time (0·05 s, for example) at the beginning of the movement, the latter is reckoned and the electro-magnetic transient phenomena. After having determined the pole-wheel angle, the angular velocity and all voltages and currents for the end of the first period, the calculation is carried out for the second interval, etc. It is clear that this means very wearisome calculations. Further, all kind of simplifying assumptions must be made which are only partially correct. For this reason, and because of having to place very small values side by side, this method gives relatively incorrect results, despite the amount of work entailed.

In order to avoid the heavy work entailed by the step-by-step method an integraph was developed by the Massachusetts Institute of Technology, that is a very complicated calculating machine to solve differential equations. The investigations carried out

[1] See for example Longley:— "The calculation of alternator swing curves. The step-by-step method." Trans. AIEE, July 1930, page 1129.

with this integraph[1] have furnished valuable contributions to the knowledge of the transient phenomena. However, there is no similar machine available in Europe for investigating any concrete case and, on the other hand, the integraph does not make experimental investigations superfluous as it does not furnish more exact data than that which is reached by the step-by-step method.

V. INTRODUCTION OF "SWING REACTANCE".

The electric and magnetic transient phenomena in the synchronous machine, in all their complexity, can only be grasped by means of tests. The setting up of a theory is necessary, nevertheless, in order to allow of applying to other cases the results of the said test. This theory must be simple enough to allow of making practical use of it (which is quite impossible in the case of the step-by-step theory). If the theory which is used is not absolutely exact, it, nevertheless, leads to results which are just as good as those attained with a so-called exact method. The "exact" method has to allow a whole series of assumptions being made in order to simplify the problem, while the approximate method looks to tests to obtain that data which cannot well be calculated.

The vectorial diagram of Fig. 7 should be studied in order to grasp the principle of an approximate

[1] See, for example Edgerton, Germeshausen, Brown and Hamilton:— "Synchronous motor pulling-into-step phenomena." Trans. AIEE, June 1933, page 342, and also Shoults, Lauder and Crary: "Pull-in characteristics of synchronous motors." El. Eng. 1935, page 1385.

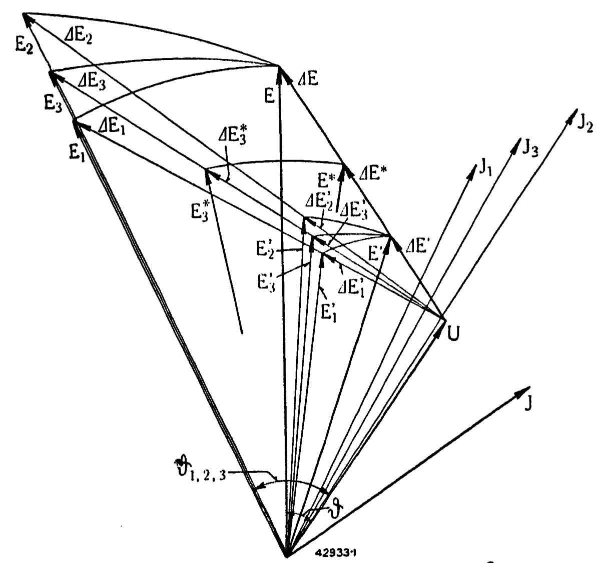

Fig. 7. — Vectorial diagram of a machine with cylindrical rotor.

Without index. Original position.
Index 1. Final position after very slow displacement.
Index 2. Final position after very rapid displacement.
Index 3. Final position after displacement at average speed.
$\Delta E = j\,x\,J$; $\Delta E' = j\,x'\,J$; $\Delta E^* = j\,x^*\,J$; x^* = swing reactance.

method of this kind. The thick-line part with the terminal voltage U, the no-load voltage E and the current J represents the initial position. The total voltage drop between U and E is $\Delta E = j x J$ in which x is the synchronous reactance. E′ the induced e. m. f. lies somewhere between the terminal voltage and the no-load voltage. The voltage drop between it and the terminal voltage amounts to $\Delta E' = j x' J$ (x' = transient reactance).

Now, the pole wheel is supposed displaced under constant terminal voltage, so that its angle is increased. As the vectorial diagram has rather too many lines, the voltage is, further, represented in cartesian

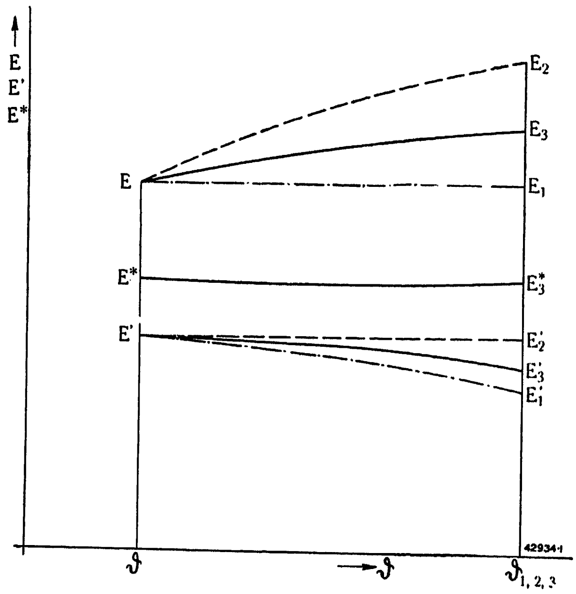

Fig. 8. — Voltages in a machine with cylindrical rotor in function of the pole-wheel angle.

Without index. Original position.
Index 1. Final position after very slow displacement.
Index 2. Final position after very rapid displacement.
Index 3. Final position after displacement at average speed.

coordinates (Fig. 8). With the initial angle ϑ, the no-load voltage has the value E and the induced e. m. f. the value E′. If, now, the pole-wheel angle is increased very slowly (that is to say slowly as compared to the magnetic time constant of the machine), the excitation current and, therefore, the no-load voltage of the machine remain constant. The e. m. f. decreases along the lower curve (E_1 and E_1'). If, on the contrary, the pole-wheel angle is increased very rapidly, the excitation current does not remain constant — as said before, but the e. m. f. does so. The no-load voltage increases along the highest curve (E_2 and E_2').

These are the two extreme cases. When the displacement is neither excessively rapid or excessively slow, the voltages change within these limit values, somewhat according to E_3 and E_3'. The no-load voltage E becomes somewhat bigger and the e. m. f. E′ smaller. Now, however, there must be a voltage somewhere between E and E′ which remains of the same magnitude before and after the displacement, this voltage is designed by E*. During the movement proper, it does not require to be exactly constant, but in calculations made it can be assumed with fair exactitude that it is so. This gives us what we require. As soon as we have a magnitude which remains constant during the displacement, we can represent the torque as a function of the pole-wheel angle and that allows us to use the favorate and simple method of surface comparison.[1]

We now go back in the vectorial diagram (Fig. 7) where the voltage E* is drawn in before and after the displacement. The voltage drop between E* and U can be written in as $\Delta E^* = j x^* J$. The magnitude x^* will be termed swing reactance, as it is the reactance which is valid for swings and other transient phenomena. It is the reactance between the terminal voltage and that internal voltage which remains constant during the transient phenomena investigated. As E* is always between E and E′, the value of the swing reactance x^* is always between the values of the synchronous reactance x and the transient reactance x'. This, however, is all that is known in advance. The exact value of x^* for different types of machines is to be determined by tests.

VI. TESTS WITH DIFFERENT ROTORS.

Two sets of tests were carried out. The object of the first one was to show the influence exercised by different rotor designs; the second one was to demonstrate how system stability is influenced by short circuits occurring on the system. For making the first set of tests, there were synchronous machines available of 110 and 150 kVA, 525 V, 1000 r. p. m. The following different types of rotor were available for investigation: — rotor with salient poles with and without damper windings, massive cylindrical rotor with copper slot keys, ditto with wooden slot keys and, finally, a laminated cylindrical rotor with a squirrel-cage designed damper winding.

All these rotors were tested according to the connections shown in Fig. 9. A D. C. motor was

[1] In Fig. 8, the behaviour of the voltages is only shown up to the moment when the pole-wheel angle reaches the new steady value ϑ_1, $_2$, $_3$, for the first time. The overswing and subsequent oscillations through the position of equilibrium is not shown.

The voltage E* is so defined that it is of the same magnitude as in the initial position, at the moment of first passage of the pole wheel through the new position of equilibrium. In the above estimation, the difference of reactances for the direct and quadrature axis is not taken into account, as the object is to show the essentials of the method, as simply as possible.

supplied from a D. C. system. The breaker S′ was first left open, therefore, resistor R is not inserted. The motor drives the machine to be tested which, itself, delivers power to an extensive network, through a 2000-kVA transformer. It was intentionally that a transformer as big as this was chosen, so that the terminal voltage of the machine being tested should remain constant during the transient phenomena. By opening breaker S, the power input on the driving side was suddenly cut off, so that the synchronous machine had to oscillate back to its no-load position. In further tests, the resistor R was inserted in parallel to the D. C. motor; to begin with, the D. C. network supplies the motor again; the synchronous machine was loaded as a generator. If the breaker S is, now, opened, not only is the power input cut off, but the resistor R takes power from the D. C. machine. The synchronous machine must drive the latter and it is, thus, loaded as a motor. This sudden reversal is the worst kind of load variations for the synchronous machine; it is considerably worse than the sudden loading of a machine running under no load. In the tests under consideration, all the important magnitudes were recorded oscillographically, especially the angle of the pole wheel and the active power of the synchronous machine.

The most significant results attained are the following: the machine never fell out of step under any of the cutting-off load tests. This is not surprising as, according to the simple theory, based on the steady torque curves, it should remain in step. But it, nearly always, remained in step under the very disadvantageous load reversals, under which, according to the said theory, it should certainly have fallen out of step. This proves that the theory in question does not take into account the real conditions pertaining:— the stability is really superior.

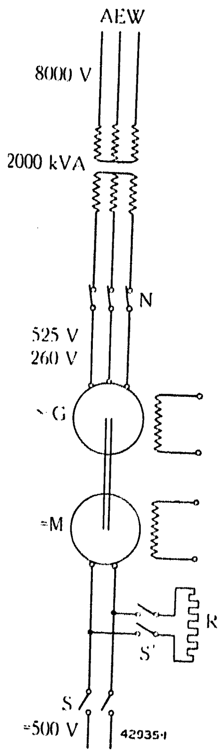

Fig. 9. — Connections for tests with various rotors.

As already mentioned, it is, chiefly, the additional currents induced in the excitation winding which are the cause of this deviation from conclusions of the simple theory. Of course, a damper winding plays a certain part. As, however, a damper winding, usually, has much less copper, its influence to improve stability is far less than that of the excitation winding. As a matter of fact, the stability of all the rotors, including those without damper winding, was far better than the simple theory would lead one to expect. Only the rotor with salient, laminated poles and no damper winding and with open excitation winding behaved according to the said theory, this because it had no closed circuit in which additional currents could be induced.

The influence of the damper winding makes itself felt by it being impossible to throw the rotors out of step by means of load changing, while the cylindrical rotor with wooden slot keys and the one with salient poles and no damper winding did fall out of step, in a few cases. On the other hand, the massive cylindrical rotor with copper slot keys behaved just as well as all those with damper windings. This does not mean, of course, that the damper winding has not some value; as a matter of fact it can render good service in certain cases, although, generally speaking, its importance is exagerated. In the majority of cases and the most important ones, practically the same results are reached by using massive poles.

The exceptionally good conditions of dynamic stability shown to exist by the tests under consideration, are not always valid for synchronous machines on systems in which big reactances due to lines and transformers etc. are inserted before the machines. The tests allow, however, of determining the swing reactance mentioned in the preceding chapter. When determined, the stability for other system conditions can be calculated. Another article will be devoted to the determination of the said reactances and with their help of the torque curves.

On the other hand, a couple of typical examples will be of interest, here, to show how much the torque of the synchronous machine is favourably influenced by the currents induced in the rotor. Fig. 10 shows the case of a cutting-off of the load with the machine with salient poles and damper winding. Curve 1 is the steady output curve with which the simple theory reckons. Curve 2 shows the real, measured curve of the active load in function of the pole-wheel angle. The rotor swings from its starting point A up to 42° and oscillates to rest in the new position of equilibrium at B. Curve 2 differs from curve 1 in the sense that, at the beginning, less power is drawn from the rotor (horizontally-shaded area instead of vertically-shaded surface) and that power is imparted to it earlier. This results in the rotor swinging about 45° less than if the steady curve 1 were valid.

Fig. 11 shows a change-over of load for the machine with salient poles without damper winding. The measured curve 2 deviates less from the steady curve 1, at the first, the damper winding not being

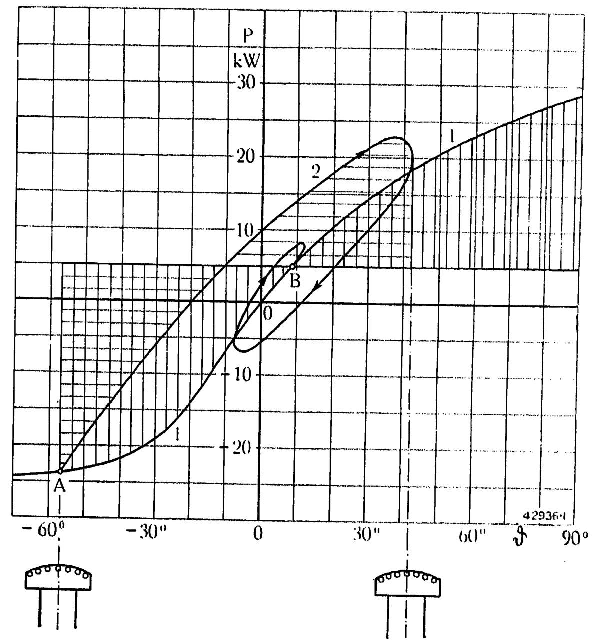

Fig. 10. — Active load in function of the pole-wheel angle when the load of the machine with salient poles and damper winding is thrown off.

Curve 1. Steady value.
Curve 2. Value measured when load is thrown off.

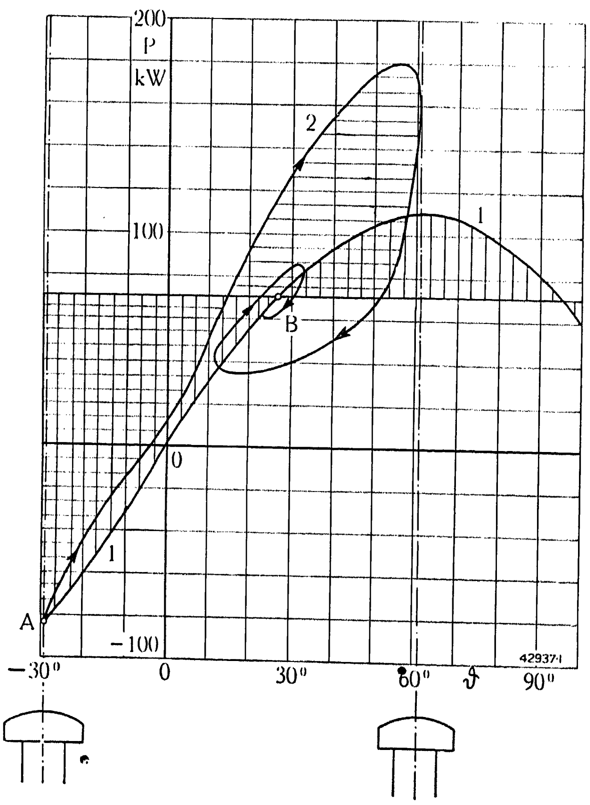

Fig. 11. — Active load in function of the pole-wheel angle when the load of the machine with salient poles and without damper winding is reversed.

Curve 1. Steady value. Curve 2. Value measured when load is reversed.

fitted. In the latter part of the curves, the excitation winding causes a greater deviation. The rotor attains a maximum displacement of 61° (equality of both horizontally-shaded surfaces). If the steady curve were valid, the rotor would have fallen out of step because the whole upper vertically-shaded area is not as big as the lower one.

Fig. 12 refers to the machine with massive cylindrical rotor and copper slot key. For curve 2, taken during a load cut out, the shading shows how very much smaller the power drawn from the rotor is, as the transient curve 2 is valid instead of the steady curve 1. The conditions with the laminated cylindrical rotor with damper winding are similar.

Apart from the behaviour of the synchronous machine when sudden angular changes take place and oscillations occur, its behaviour under asynchronous running is a matter of interest. This must be ascertained if it is desired to investigate whether a machine which has fallen out of step or one started asynchronously will pull into step. To this end, the couple of cases in which the machines under test fell out of step were made the subject of close investigation. The machines which never fell out of step when load change-overs were carried out, were thrown out of step by increasing the load beyond the static limit load. As an example, Fig. 13 shows the throwing

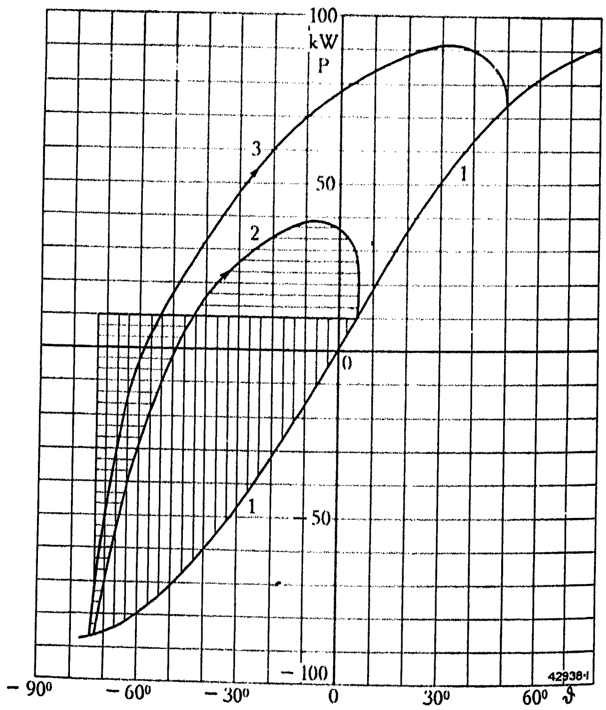

Fig. 12. — Active load in function of the pole-wheel angle when the load is cut out and load is reversed, in the case of the machine with massive cylindrical rotor and copper slot keys.

Curve 1. Steady value.
Curve 2. Value measured when load is cut out.
Curve 3. Value measured when load is reversed.

out of step of the cylindrical rotor with damper winding. The pole-wheel angle grows bigger than 180° and is indicated again below in the diagram, it then slips regularly. The active power fluctuates periodically. The asynchronous output is always positive and corresponds to the average value. The total output fluctuates round this average value and these fluctuations correspond to the synchronous load. The pole-wheel angle passes through the whole 360° and, in so doing, the synchronous output passes through positive and negative values (compare with Fig. 3). Such oscillographic records as those in Fig. 13 allow of determining the average load and amplitude of the pulsating load. The average or asynchronous output is shown in Fig. 14 in function of the slip. Curves 2 and 4 show the branch of the power curve which begins by being about straight, then rises slowly and falls again. The measuring points of curve 5 appear entirely located in the straight part while those of 1 are on the falling branch. For the sake of interest, the very low values of the machine with open excitation winding are shown (curve 3).

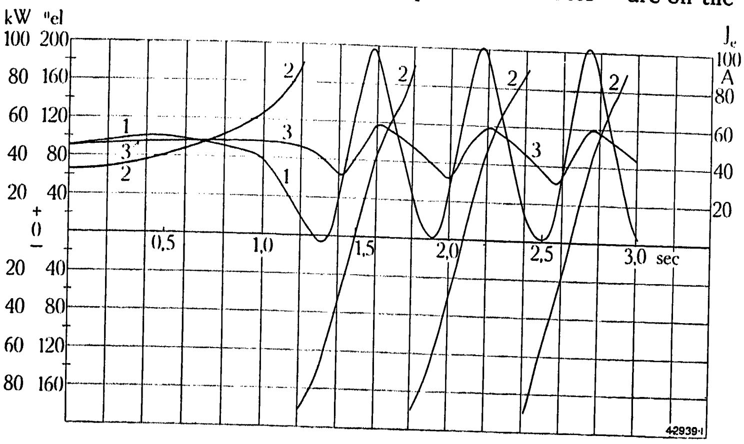

Fig. 13. — Machine with cylindrical rotor and damper winding thrown out of step by exceeding the static load limit.

Curve 1. Active load.
Curve 2. Pole-wheel angle.
Curve 3. Exciter current.

The amplitudes of the pulsating outputs are given in Fig. 15, in percentage of the maximum output of the steady output curves. Apart from the machine with open exciter winding, the amplitudes of the pulsating outputs do not deviate much from the steady limit output (curves nearly 100 %).

VII. STABILITY TESTS UNDER SHORT CIRCUITS.

We now pass to the second class of tests, for which the connections shown in Fig. 16 are valid. The turbo-generator used is of 2300 kVA, p. f. = 0·7, 3000 r. p. m. It runs in parallel with a very extensive network with a total generator output of about 100 MVA. Sudden short circuits were produced through choke coils which, here, represent a branch line. The duration of the short circuits was made to vary between some tenths and a full two seconds. The short circuits were, partly, three and, partly, two-pole ones. By means of different reactances of the choke coils the strength of the short circuits could be controlled. Under the heaviest short circuits, the terminal voltage of the generator was suddenly reduced to about 30% and to 20% under lasting short circuit. The generator ran with different preliminary

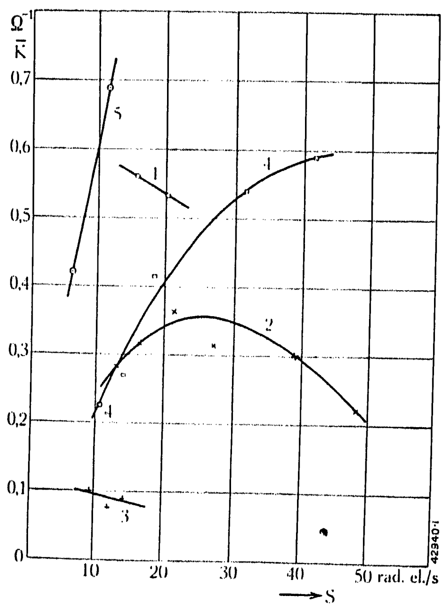

Fig. 14. — Asynchronous-load factor in function of the slip.

Curve 1. Salient poles with damper winding.
Curve 2. Salient poles without damper winding.
Curve 3. Salient poles without damper winding with open excitation circuit.
Curve 4. Massive cylindrical rotor with copper slot keys.
Curve 5. Laminated cylindrical rotor with damper winding.
S. Slip.

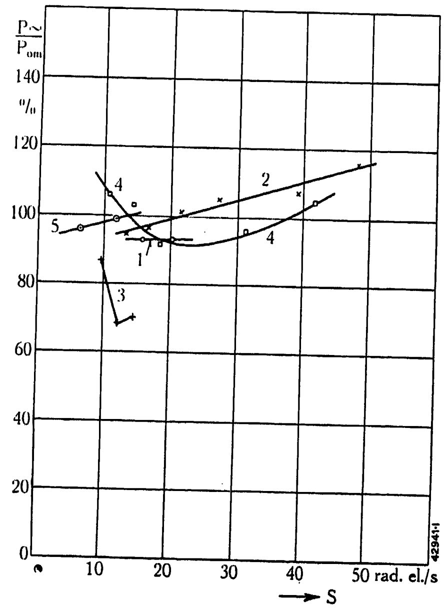

Fig. 15. — Amplitude of pulsating load for asynchronous running in % of static limit load.

Curve 1. Salient poles with damper winding.
Curve 2. Salient poles without damper winding.
Curve 3. Salient poles without damper winding with open exciter winding.
Curve 4. Massive cylindrical rotor with copper slot keys.
Curve 5. Laminated cylindrical rotor with damper winding.
S. Slip.

loads of $^3/_4$ up to over the full-rated load, at p. f. = 1 and 0·8. The excitation current was provided by a direct-coupled exciter and was not regulated during the short circuit. The regulator of the turbine was operating normally. A number of tests were also carried out with the steam supply cut off, in which case the synchronous machine runs as phase advancer (synchronous condenser), and, this, both over and underexcited and at p. f. = 1.

This big class of tests, as well, causes surprise by showing better stability than might be expected. Running as a generator, the machine never fell out of step when it carried a $^3/_4$ preliminary load and voltage was dropped to 60 % at the first moment and by 40 % in continuous short circuit. With heavier preliminary loading or lower drop in voltage it is true that it did fall out of step when the three-pole short circuit lasted long enough, but soon gained a steady asynchronous condition with a slip of always less than 9 %. The instantaneous closing device of the turbine never acted. As soon as the short circuit was cleared the generator was pulled into step again after very few slips. An important point to be noted is that the generator never fell out of step, even under the worst conditions, when the short circuit did not exceed 0·4 seconds duration.

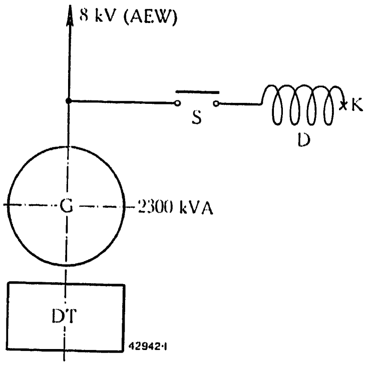

Fig. 16. — Diagram of connections for stability tests during short circuits.

D. Choke coil.
DT. Steam turbine.
G. Generator.
K. Point at which short circuit occurs.
S. Short-circuit breaker.

The generator was never thrown out of step by the two-pole short circuits, whatever their duration. There are two reasons why the two-pole short circuit is more favourable than the three-pole one. Firstly, with the same voltage drop of the affected phases, the positive-sequence voltage is considerably greater in the case of a two-pole short circuit. Secondly the negative-sequence current of the two-pole short circuit produces a considerable braking effect which is counter to the action of the turbine. This is very advantageous, because the speeds of loaded generators generally tend to rise under the effect of short circuits. In the case of synchronous *motors*, on the contrary, this braking effect is disadvantageous as it adds to the ordinary load of the machine driven, and, thus, favours a falling out of step.

When the machine runs as a phase advancer, it was never thrown out of step either under two or three-pole short circuits. The pole wheel simply oscillates during the short circuit and comes back to its original position once the short circuit is cleared.

A couple of typical curves from these tests are reproduced in Figs. 1, 17 and 18. Fig. 1 shows a violent three-pole short circuit in which the generator falls out of step. Fig. 17 shows a two-pole short circuit under, practically, the same conditions. The pole-wheel simply oscillates a couple of times, the pole-wheel angle never exceeding 35°. After the short circuit has been cleared it swings to 47° (the braking effect of the negative-sequence current has been removed). Then it regains its original position. Fig. 18 shows a violent three-pole short circuit when the machine is running as a phase advancer and this under disadvantageous condition of a weak excitation (p. f. = 1). Here, also, the pole wheel simply oscillates a few times.

The very favourable results of the tests just explained cannot be applied without modification to other network conditions. In the tests made, the synchronous machine was connected to a powerful system through relatively low impedances. If, however, there are longer lines and greater impedances, the transient stability will certainly be poorer. The machines will fall out of step under lower preliminary loads and slighter voltage drops. Further, there is a possibility that they will not be pulled back into step again after the short circuit has been cleared. One factor, however, remains valid for any network conditions: the machines will not be thrown out of step if the duration of the short circuit does not

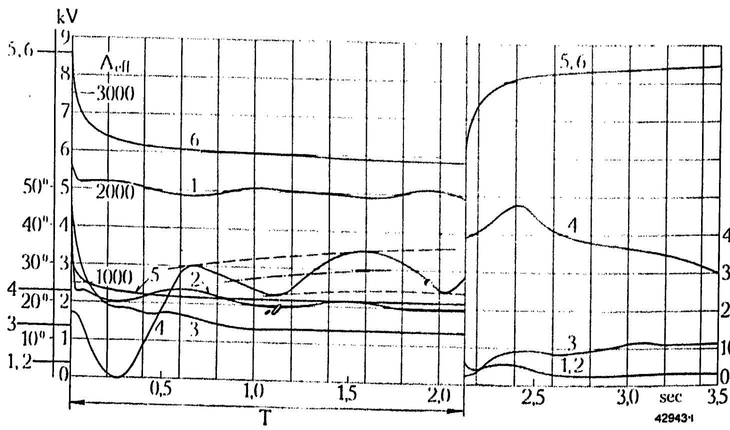

Fig. 17. — Two-pole short circuit (phases R and T) with connection according to Fig. 16. Preliminary generator load 1690 kW, p. f. = 0·8.

Curve 1. System current phase R.
Curve 2. Generator current phase R.
Curve 3. D. C. component of excitation current.
Curve 4. Pole-wheel angle.
Curve 5. Terminal voltage RT.
Curve 6. Terminal voltage ST.
K. Duration of short circuit.

exceed 0·3 to 0·4 seconds, because, under any conditions, it takes this time for the rotor to carry out the requisite displacement to fall out of step. The duration of the inherent oscillation of standard synchronous machines is always of the order of one second.

VIII. MEASURES TO IMPROVE STABILITY.

The question arises: — how can stability be improved in cases where it is unsatisfactory? As already said, the static stability is never in danger, in practical cases. As regards transient stability, a distinction must be made between several different cases. In the coupling of synchronous machines with reciprocating engines, where there is a danger of oscillations, a suitable choice of the reactances and of the inertiae must be made so that the pulsations of the driving torque do not come into resonance with the inherent frequency of the pole-wheel oscillations. In such cases an increase in damping by a suitable damping winding may be advantageous.

A second class of disturbances is due to sudden changes in network conditions such as switching in and cutting out loads, the cutting out of parallel lines, etc. All these changes must be stood up to by the machines without *special* measures being necessary, this by suitable layout of the system. This means heavy connecting lines, for example, in sufficient number. The smaller the reactances and ohmic resistances between the different power stations and substations the better are the conditions of stability. In such cases, the reactances and resistances have always got to be reduced to the same common voltage, so that, with lines of the same section, they appear the smaller the higher the transmission voltage is. Further, constructive measures taken on the synchronous machines, themselves, may better stability, in which field, however, the part played by damping windings should not be overestimated. An increase in the flywheel effect generally improves the stability, but this is not always the case. It is, also, advantageous when the different generators and driving engines with their governors working in parallel are of as much the same type as possible and when the active and reactive load delivered by a station is as evenly distributed among the units as possible.

By far the greatest danger for transient stability is the case of short circuits. Here, as well, the general conditions of the system, just mentioned, play an important part. Further, the duration of the short circuit is of great importance. It has already been laid down that falling out of step can, always, be avoided when the short circuit is cleared in a maximum time of 0·3 to 0·4 seconds. Let us, for the sake of safety, set the limit *at* $^1/_4$ *second*[1]. Here, however, a limitation must be imposed. Stable parallel operation can, naturally, only be guaranteed unconditionally, with such a rapidly operating selective protection system, when there are sufficient spare lines available. If a connecting line is cut out as a result of a short circuit, there must be, nevertheless, some connection of sufficient power-carrying capacity.

Impulse excitation (also termed super-speed excitation) offers some possibilities to improve stability. By this means, the excitation current and, therewith, the field are kept up artificially during a short circuit, which results in an increase of the synchronous torque and thus an improvement of stability. Impulse excitation, however, is only an emergency aid. The solution of the problem of stability lies in the selective system with a maximum of tripping time set of $^1/_4$ of a second (for relay and breaker together). Impulse excitation has, of course, the undesirable result of increasing the short-circuit current and there are always cases in which it does not prevent falling out of step, thus, for example, in the case of direct three-pole short circuits on important connecting lines, in which cases it can only do harm.

The advantages of impulse excitation only appear when it is able to increase the excitation current excessively quickly. The impulse excitation systems described in the technical press call for 0·6 to 2 seconds, however, to build up the field. This is of little use for the cases considered. On the other hand, it is impossible to decrease below about 0·5 seconds the time requisite to build up the field, because the magnetic time

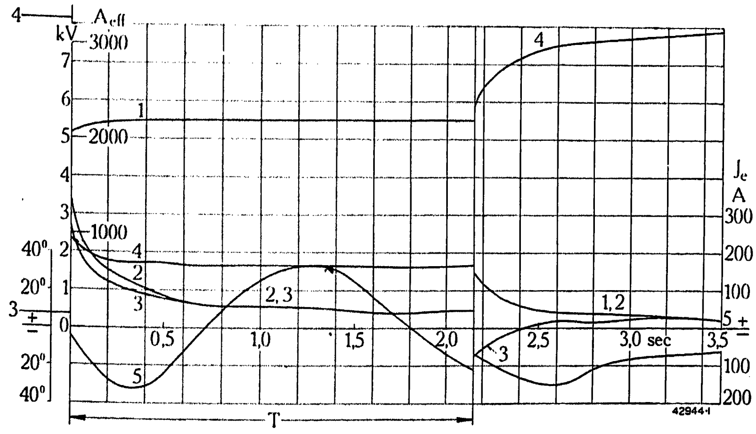

Fig. 18. — Three-pole short circuit with connections according to Fig. 16. Operation as phase advancer at p. f. = 1.

Curve 1. Network current.
Curve 2. Generator current.
Curve 3. D.C. component of excitation current.
Curve 4. Composed (line) terminal voltage.
Curve 5. Pole-wheel angle.
T. Duration of short circuit.

[1] This time is, of course, not for the relay alone but also for the whole breaker trip.

constant of the synchronous machine and its exciter must be overcome. There is, however, another way of effecting a considerable improvement. As is known, in case of a short circuit, the field is maintained for an extremely brief period, at first, but then, falls away very rapidly. If a way is found to prevent this fall or to retard it, stability can be considerably improved as compared to the ordinary short-circuit phenomena. In this case, it is not necessary to overcome the time constant of the synchronous machine, the field not having to be built up but only to be maintained. To get a successful result, the voltage of the exciter must be raised excessively rapidly, so that the initial big excitation current falls as little as possible. The best way is to make use of the big excitation current of the generator itself in order to raise the voltage of the exciter.

Fig. 19 shows the principle of two systems of connection of the kind in question, developed by Brown Boveri.

Both connections make use of a main and auxiliary exciter as do the systems of impulse excitation already known from technical publications. The auxiliary exciter supplies the standard excitation of the main exciter through a quick-acting voltage regulator, the main exciter excites the generator. In both cases, the main exciter has a second excitation winding, as well, of series character. In the upper connection shown, this second winding is deprived of current under ordinary conditions; but, at the moment of short circuit, when the excitation current of the generator jumps up, a series transformer induces a current in the winding H which lasts some time.

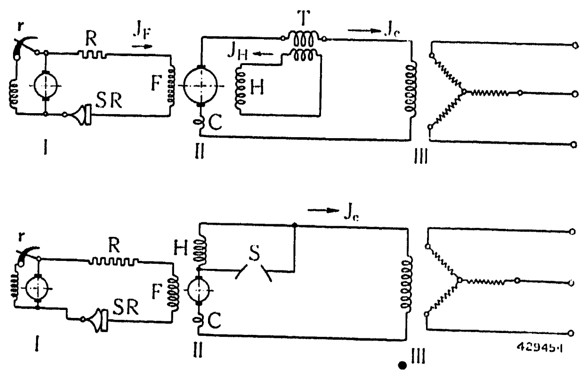

Fig. 19. — Impulse-excitation connections.

Above:— with series transformer in excitation circuit.
Below:— with high-speed breaker in excitation circuit.

I. Auxiliary exciter.
II. Main exciter.
III. Generator.
C. Compound winding of main exciter.
F. Separate-excitation winding of main exciter.
H. Series-excitation winding of main exciter.
S. Quick-acting regulator.
SR. Quick-acting voltage regulator.
T. Series transformer.

In this way, the voltage of the main exciter, in the case of short circuit, can be increased very quickly. The additional current in H causes the higher voltage to be maintained until the voltage regulator makes itself felt. In the lower connection, the winding H is directly in series with the excitation winding of the generator. It is, however, under ordinary conditions, short-circuited by a quick-acting switch, and is under no current. In the case of a short circuit, the said switch opens so that winding H generates a high voltage in the main exciter. As tests show, suitable control of the switch allows of opening it so rapidly that the full exciter current flows through H after as short a period as 2/100 seconds.

Both connections are about equal in effect. The outlay for the impulse excitation is the following:— in both cases an abnormally big exciter with laminated poles and yoke must be available. In order to attain good results, it should at least be four times bigger than the standard exciter. The upper connection calls for a quick-acting regulator which can fully govern the big exciter. The lower connection requires a high-speed breaker and the upper one requires a series transformer in its place. The output of this transformer does not require to be more than about 4% of the generator output.

The successful results arrived at with our impulse-excitation systems are apparent in Fig. 20. The curves are recorded with the same generator [1] as used for the tests described in the preceding paragraphs and this with a three-pole short circuit which brings down the terminal voltage to about 40% in the initial moment. The lower curve shows the drop in terminal voltage when the excitation current is not regulated at all. The middle curve is recorded when a good quick-acting voltage regulator is used, the upper curve, when impulse excitation is applied according to the upper connection shown in Fig. 19.

The stability improves as the terminal voltage increases and the longer it remains high. The figure shows, clearly, the considerable improvement in stability due to the impulse excitation.

To conclude, a few words should be said on the effect of the current-limiting regulator on system stability. From what has been said here, it is seen that a reduction in the excitation during a short circuit is unfavourable, in most cases. Even when the generators fall out of step as a result of the short circuit, a certain minimum excitation is requisite

[1] But connected for 4000 V.

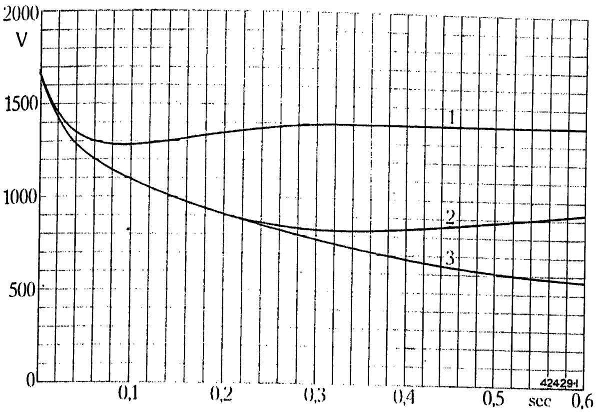

Fig. 20. — Curves of terminal voltage of a turbo-generator of 2300 kVA, 3000 r. p. m., 4000 V, in the case of a three-pole short circuit through choke coils, with and without impulse excitation.

1. With impulse excitation.
2. With quick-acting voltage regulator.
3. Without regulation.

to allow them to be pulled into step again. The current limiting regulator must not, therefore, produce a stronger counter effect than this or else it becomes harmful. A reduction of excitation down to this limit is, however, very advantageous as this means a reduction of the transient currents and outputs flowing and also because undesirable reactions on the turbine governor tend to be diminished in this way. Further, in many cases, the pulling into step of generators which have fallen out is, often, easier to accomplish at weaker excitation. The current-limiting regulator should have a retardation corresponding to about the time necessary for the selective protection. In so far as the trouble persists after that period, the current-limiting regulator should act but, when it does so, it must not underexcite too low. When there are very violent short circuits such, for example, as bus-bar short circuits on three poles, the current-limiting regulator should be allowed to act at once, because, here, stability cannot be kept up, in any case and the object is to reduce the short-circuit currents as quickly as possible.

To summarize, it can be said that the basis of good stability lies in the suitable layout of the system, and here the main factor is to have sufficiently strong transmission lines. The best means of assuring stability even when short circuits occur is to have a quick-acting selective protection system and here quick relay and quick breaker-trip times are of equal importance. In many cases a suitable system of impulse excitation will improve stability, but it must act extremely quickly (within a few hundredth parts of a second). The current-limiting regulator, also, can improve stability, if properly used. It can be combined quite well with the impulse excitation equipment, in such a manner that when a short circuit occurs, the latter equipment first acts alone and the current-limiting regulator only intervenes when, despite all measures, the machines fall out of step or when the short circuit persists after the passing of the ordinary tripping time of the selective protection equipment.

(MS 530) *Dr. W. Wanger. (Mo.)*

TRANSFORMATION OF TWO PETROL-ELECTRIC MOTOR COACHES OF THE DIEKIRCH-VIANDEN (LUXEMBURG) NARROW-GAUGE RAILWAY.

Decimal index 621. 335. 4. 033. 44 (435.9).

IN the 1924—1936 period there were — apart from steam-hauled trains — two petrol-electric motor coaches running on the Diekirch-Vianden line section of the Luxemburg narrow-gauge system, which section is 14 km long and comprises many curves and stiff gradients. These two units had handled suburban traffic between Luxemburg and Eich in the years 1912—13 and had, then, been relegated to a locomotive shed for the duration of the war and afterwards, up till the year 1924. These motor coaches were equipped with a petrol engine, 90 H. P. at 950 r. p. m. and an electric power-transmission equipment delivered by the Westinghouse Company in Le Havre. Twelve years of severe service made a renewal of the machinery plant essential and the opportunity was taken to modernize a service which had ceased to pay, to speed up the coaches, while, at the same time, lowering running charges; these improvements were imperative on account of the very unsatisfactory conditions inherent to steam-locomotive haulage on this line and, also, on account of the menace of increasing automobile competition. The railway management decided to replace the petrol engines by more powerful Diesel units and to transform the electric equipment and control to meet the new conditions. In accordance with the specification of the Railway Co., the available power of the reconditioned motor coaches had to be sufficiently increased to allow of

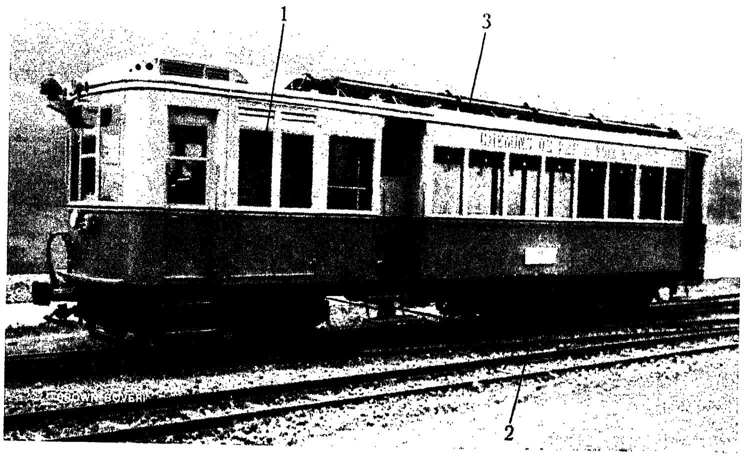

Fig. 1. — Motor coach No. 4 of the Diekirch-Vianden Narrow-gauge Railway, after transformation to Diesel-electric drive.

1. Engine room with Diesel-generator set, placed transversally to longitudinal axis of coach.
2. Bogie carrying the driving motors.
3. Cooler for the circulation water to cool the Diesel engine.

covering the same line section in 29 instead of 42 minutes, including seven stops of each 30 seconds, this with a trailer of 13 t, when loaded.

The order for the transformation of the two motor coaches was placed in open competition with the Compagnie Industrielle pour l'Application des Procédés Brown Boveri, Brussels, to be carried out by Brown, Boveri & Co., Ltd., Baden.

Fig. 1 shows one of the motor coaches after transformation, the chief characteristics of which are given herewith.

Gauge	1000 mm
Total length over buffers	13348 mm
Axle arrangement	2—2 A, two two-axle bogies, of which one with two driving motors.
Diameter of driving and carrying wheels	800 mm
Tare	28 t
Weight in running order with load	32 t
Number of passengers seated	32
Number of passengers standing	20
Area of luggage compartment	abt. 2·5 m^2
Area of machine plant with driver's cab	abt. 6 m^2
Rated continuous Diesel output	180 H.P. at 1180 r.p.m.
Maximum travelling speed	60 km/h

The very strong *coachwork* of these cars stood up well to the twelve-years service to which they had been subjected and no alterations were necessary here, apart from a strengthening of the suspension springs of the bogie below the engine room and a new coat of paint. The existing Westinghouse compressed-air brake, only working on the bogie frame carrying the driving motors, was completed by the building in of a brake cylinder with brake-shoes on the other or runner-wheel bogie under the engine room. A special supporting-frame design had to be used to allow of replacing the old, completely enclosed, driving motors by more powerful units with auto-ventilation, on account of the smaller dimensions of the latter. The locating of the Diesel-generator set offered certain difficulties as it had to be lodged, crosswise to the longitudinal axis of the coach, in an engine room of fixed dimensions and also because there were certain reasons for not putting in very high-speed Diesel engines.

The Diesel engines (Fig. 2) were built by the Humboldt-Deutz Motoren A.-G., Cologne-Deutz. The engine used is of the six-cylinder four-stroke cycle type built to the pre-combustion chamber system. The output is 180 H. P. continuous rating at 1180 r. p. m. and 200 H. P. one-hour rating at 1180 r. p. m. (four fixed service speeds, 600 r. p. m. at no load and 630—850—1100—1180 r. p. m. at full load).

The governor is a high-speed pendulum governor carried on knife-edges which influences the fuel charge (filling) through the agency of a servo-motor by variation of the piston stroke of the fuel pump with the help of an inclined cam. The fuel consumption at full load amounts to 190 g/H. P. h and the consumption of lubricating oil to 3·5 g/H. P. h. Starting the Diesel engine is carried out by means of

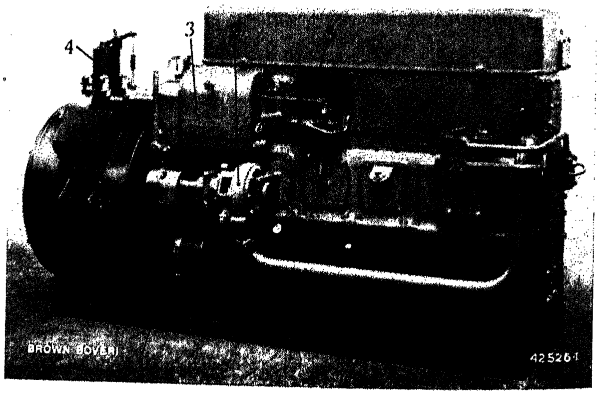

Fig. 2. — Diesel-generator set.

1. Starting motor.
2. Cooling-water pump.
3. Centrifugal governor.
4. Electro-pneumatic speed adjuster.
5. Servo field-regulator.

two built-on starting motors each of 6 H.P. fed from a storage battery. When the Diesel engine is cold, the incandescent glow plug projecting into the pre-combustion chamber is switched in before the starting is carried out.

The Diesel engine together with the rigidly-coupled generator are bolted down on a very heavy bed frame. The latter is bolted to the frame of the coach, a layer of felt, 20 mm thick, being inserted between them. The Diesel-generator set can be put in or taken out sidewise, without removing the roof of the coach.

To meet the specification of the railway company, the existing water cooler on the roof of the coach had to be used and made to suit the new engine output by the addition of similar additional coolers. The cooler is composed of ribbed tubes of a total cooling surface of 17 m^2. It would have been possible to make a new cooler having considerably smaller dimensions and higher efficiency.

In the former petrol-electric machine set, the motor compressor for producing the compressed air for braking (rated output 6·5 H.P. at 600 V) and the heating plant (3 kW at 550 V) were connected up to the generator while a small belt-driven charging dynamo was used to charge the 12-V storage battery, for lighting. In transforming the coach, the design and layout of the new *electric equipment* had to take into account that the said motor compressor and heating plant were to be taken over as they were while the lighting plant had to be renewed and its voltage raised to 24 V. The voltage ratio of the main and the auxiliary service circuits were, thus, determined in advance. Given the very restricted length available for the machinery set, it was impossible to overhang an auxiliary generator on the shaft end of the Diesel generator set, while the placing of the auxiliary generator on the top of the main one and driving it by belt, seemed undesirable to judge by the poor results obtained earlier in other plants with this arrangement. The simplest and most practical solution was to use a voltage converting set, converting the variable voltage of the generator to a practically constant voltage of 24 V. The general connections used were the following:— the two driving motors of the coach are connected to the generator continuously and in parallel, the same applies to the motor compressor, the electric heating of coach and trailer and the voltage-converting set. The latter supplies the separate excitation of the main generator, the starting battery, the control and the lighting current circuit.

The self-ventilated *generator* (Fig. 3) has only one flange bearing, designed as a roller bearing and located on the commutator side while on the coupling side the generator armature is supported on the Diesel-engine bearing. The geared rim with which the two pinions of the two starting motors of the Diesel engine mesh, is secured to the generator fan-wheel. The generator is a six-pole machine, built for a one-hour rating of 112 kW (402 V, 278 A) and a continuous rating of 116 kW (546 V, 212 A) at 1180 r. p. m.; it has self excitation as well as separate excitation and a counter-compound winding as well, to limit the maximum current at starting. There are no over-current relays in the circuit of the driving motors.

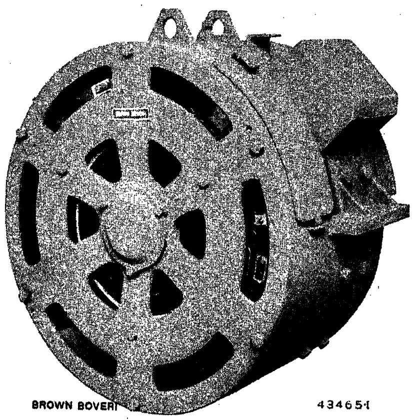

Fig. 3. — Generator of single-bearing design for rigid coupling to Diesel engine.
View of flange bearing of generator.

The *driving motors* are self-ventilated, four-pole, series-connected units of the axle-bearing type. The armatures have roller bearings while the axle bearings are bush bearings with pad lubrication. The motors are built for a one-hour rating of each 64·5 H.P. (402 V, 133 A) at 922 r. p. m., corresponding to a coach speed of 24·5 km/h with driving wheels of 760 mm diameter (worn-tire diameter) and a reduction gear ratio of 1:5·78. The highest allowable service speed is 2800 r. p. m. Taking into account an average constant power output of 15 H.P. (heating included) for the auxiliary services, the following tractive effort at the wheel tread and speeds are reached at continuous Diesel output rating:—

at the start:— 2800 kg from 0 up to 9·5 km/h;
at one-hour load rating of the electric power transmission equipment:— 1380 kg at 24·5 km/h;
at continuous-load rating of the electric power transmission equipment:— 860 kg at 40 km/h.

The voltage-converting set, located in the engine room, is composed of a D. C. compound motor

built into a common housing with a D. C. shunt generator. The motor is connected straight to the terminals of the main generator and is, thus, supplied at variable voltage of 220 to 630 V. The generator of the voltage-converting set delivers a voltage of 26—30 V to charge the starting battery and to supply the control circuit and the lighting circuit. A quick-acting voltage regulator is used to regulate the generator voltage, through influencing the field of the latter.

The storage battery (lead battery, built by Tudor) is composed of four cases each holding six accumulator elements of 320 Ah capacity under a 5-h discharge. The rated discharge voltage is 22 V at 64 A.

The control.— There is a controller in each driver's cab to adjust the tractive effort and speed and to make the requisite adjustments for travelling. This controller has the following control drums: a main (running) drum with a locking position, a dead position and seven service positions; a secondary drum with a dead position and four service positions. The driver adjusts the speed and output of the Diesel engine by means of the main or running drum. The sense of rotation of the driving motors is determined by the secondary drum and the latter is equipped to this end with heavy-current contacts. The secondary drum also serves for changing-over operations on the auxiliary services, when the coach is travelling or stopped with the Diesel engine running.

The *speed-adjusting apparatus* shown in Fig. 4, which is of the electro-pneumatic type, is used to alter the tension of the spring of the centrifugal governor when the speed of the Diesel engine is being set. There are five compressed-air pistons controlled by electro-magnet valves lodged in the housing of the speed-adjusting apparatus. These pistons adjust the spring of the governor through the agency of a rod (Fig. 2). The no-load speed is adjusted to for starting the Diesel engine, in which adjustment the governor gives the necessary fuel charge for starting to assure reliable starting up. Stopping the Diesel engine is carried out by cutting off current from all the electro-magnets of the aforementioned valves. This causes the spring of the governor to be sufficiently slackened to reduce the fuel charge to such a degree that the engine stops.

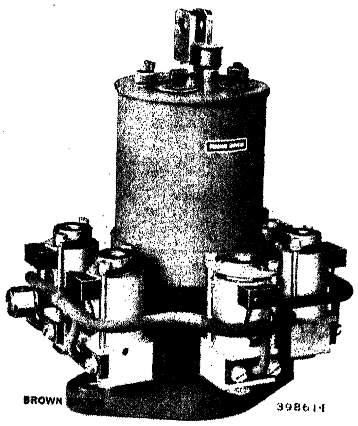

Fig. 4. —Electro-pneumatic speed adjuster.

With five compressed-air pistons for six adjustable steps, including a dead position; total range of adjustment travel 50 mm; steps 1 to 4 can be adjusted as desired. Adjustment force up or down 10 kg at a minimum effective pressure of 3 kg/cm².

The motor coaches are equipped with the Brown Boveri *servo field-regulator control.*[1] In order to attain seven regulating steps with the four fixed service speeds of the Diesel engine, the torque is stepped at constant speed (r. p. m.) by electro-magnets built on to the servo field-regulator. The output adjustment for the different control steps is given in the following table (page 115).

Fig. 5 shows the characteristics of the generator and the regulating curves of the servo field-regulator control for the three fixed service speeds: 1180, 1100, 630 r. p. m. At 25 V separate excitation, there is a maximum starting current of 475 A (point of intersection of curve 1 with the straight line of the resistance 4).

The separate excitation-current circuit of the generator consists of two parallel branches, one of which supplies the constant "basic excitation", while the other is regulated by the servo field-regulator. If a defect develops on one of the driving motors, the "regulated excitation" and, therewith, the servo field-regulator is cut out at the same time as the motor in question is cut out. The control now works as "characteristic

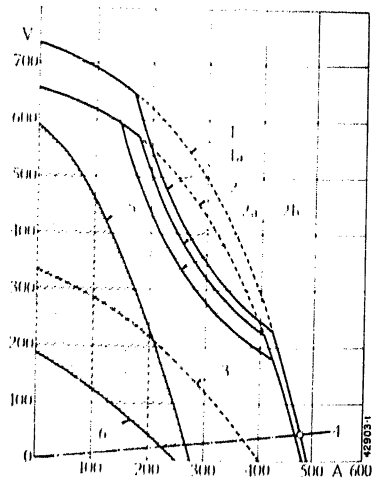

Fig. 5. Generator characteristics and regulation curves of control by servo field-regulator.

1, 2, 3. Voltage in function of current strength at constant service speeds of 1180, 1100 and 630 r. p. m. and maximum separate excitation at 25 V.

1a, 2a, 2b. Generator voltage regulated by the servo field-regulator in function of current strength at 1180 r. p. m. and 100% torque; 1100 r. p. m. and 100% torque; 1100 r. p. m. and 85% torque.

4. Resistance straight line of the load-current circuit.

5, 6. Voltage in function of current strength with weakened separate excitation (excitation current branch of servo field-regulation cut out) at constant speed (r. p. m.) of 1180 and 630 r. p. m. respectively (service with one driving motor only).

[1] See The Brown Boveri Review, year 1935, No. 12, page 239.

Running step	Diesel-engine output			
	Speed (r. p. m.)	Torque in %	Output in H. P.	Output in %
1	630	85	82	45
2	850	85	110	61
3	850	100	130	72
4	1100	85	143	79
5	1100	100	168	93
6	1180	100	180	100
7	1180	111	200	111

control" and allows of service being maintained. The conditions are so chosen that under standard separate excitation voltage the driving motor which remains in service can only be loaded within the area enclosed by characteristics 5 and 6 and, also, that the allowable starting current cannot be exceeded even under maximum separate excitation voltage.

The control is combined with a *safety device* that starts up at once when the safety pedal is released during running.

Service results.

Taking-over trial runs were carried out, with the first coach transformed, on the 30/31 of March, 1936 and with the second one on the 7/8 July, 1936. These runs were accomplished under perfect conditions and to the great satisfaction of the railway authorities. All the conditions of the specification were fulfilled. Since then, both coaches have been running to standard time table and had covered more than 15,000 km up to the end of August 1936, without the slightest case of trouble developing (average running speed of coach about 30 km/h. A comparison of fuel costs with steam, petrol-electric and Diesel-electric service gives the following results, referred to a double trip on the Diekirch-Vianden line section (about 28 km).

(a) Steam propulsion :—
250 kg of briquettes, in Luxemburg Frs. 144.75 per ton, plus 10 % extra for getting up steam 39.80

(b) 90 H. P. petrol-electric motor coach 28 l of petrol in Luxemburg Frs. 50.40

(c) 180/200 H. P. Diesel-electric motor coach 20 kg fuel oil in Luxemburg Frs. 10.40

Apart from the considerably bigger power available with the coaches transformed for Diesel-electric service, there is a fuel saving on the double trip as compared to the former petrol-electric service, of Lux. Frs. 40.—. The difference is smaller when compared to steam service, but it must not be forgotten that a saving is affected by the elimination of an engine stoker.

(MS 522) *A. E. Müller. (Mo.)*

NOTES.

The coal-handling plants in the coal port of Born (Holland).

Decimal index 621. 34: 621. 869. 247 (492).

THE coal port at Born on the Juliana Canal, in Holland, has been equipped to allow of handling and storing two million tons of coal, annually. A capacity of this order can, however, only be attained with the help of special handling devices built to meet the particular needs of the case. As, generally, the coal is transhipped from railway trucks to lighters, the solution adopted was the essentually modern one of a truck-tipping machine, which allows of bulk transhipment, the necessary precautions being taken to prevent the coal being broken up in the process, which would reduce its commercial value.

As early as 1934, the Dutch Railways put a high-capacity truck-tipping machine into service. The mechanical part thereof was delivered by the Demag Co. of Duisburg and the electrical equipment by Brown Boveri. This machine is chiefly used for handling industrial grades of coal and allows of unloading about 300—350 trucks of 20-tons capacity each in 24 hours. This truck-tipper, which can develop 45 tons, is composed of a gantry, which is fixed, carrying the travelling mechanism to which the platform is suspended which tips the entire trucks. Control is from a cab secured to one of the gantry feet. The plant is completed by a capstan system, by turn tables and various auxiliary devices which allow of bringing the full trucks on to the platform and of despatching the empty ones on the desired railway track.

The hoisting mechanism is driven by a three-phase induction motor of 125-kW output, built for 40 % switching ratio and for 725 r. p. m., which is connected in the Brown Boveri sub-synchronous braking connection at lowering, by inversing one stator phase. This connection allows of electric braking when the platform is being tilted and of a speed regulation over a wide range below the synchronous speed of the motor. The service results attained with this truck-tilting machine were so satisfactory that the Dutch Railways decided to place an order for a second one, built to the same principle.

This second truck-tipping machine, shown in the illustration on the cover of this number, was put to work in 1935; it is designed to develop 45 tons, as was the earlier one, and is chiefly used for handling household coal. The mechanical part was built by the J. Pohlig Co. of Cologne and differs considerably from that of the first unit. The design recalls the classic gantry, surmounted by a slewing crane. The machine is composed of a moving

gantry, 59 m long, leaving between its supports sufficient space for six parallel full-gauge railway tracks. On the upper part of the gantry, there are rails on which the slewing crane runs. The trucks are run on to a platform located for that purpose, and are locked on the said platform which is then raised into the position shown in the illustration on the cover of this number. The next operation consists in tilting the platform, the coal pours down a funnel, suitable placed, and is guided by channels on to a conveyor belt running the length of the bridge. The illustration on the cover shows that this conveyor belt can be lowered at its canal end in order to allow of straight loading of lighters and, thus, preventing coal being broken through falling from a considerable height.

This machine can handle 160—190 trucks in a 16-hour working shift.

The electrical equipment is supplied with three-phase current at 380 V, 50 cycles. The hoisting and tilting mechanism consists of two motors each of 155 kW for 40 % switching ratio. The transition mechanism of this crane is driven by an 80-kW motor while the portal itself is driven by a 125-kW motor. The travelling and rotation mechanisms are equipped with standard reversing connections, but the hoisting and tilting mechanism have the Brown Boveri sub-synchronous lowering braking by inversion of one phase, as in the first machine. With this connection, braking is attained simply by inversing one of the stator phases by 180 electrical degrees. The passage from the braking position to that of accelerated lowering is performed without suppression of the magnetic field. The motor, thus, continues to generate a torque during the commutation. There is, therefore, no free-fall position and it is impossible for the platform carrying the truck to attain a dangerous velocity as a result of a faulty operation.

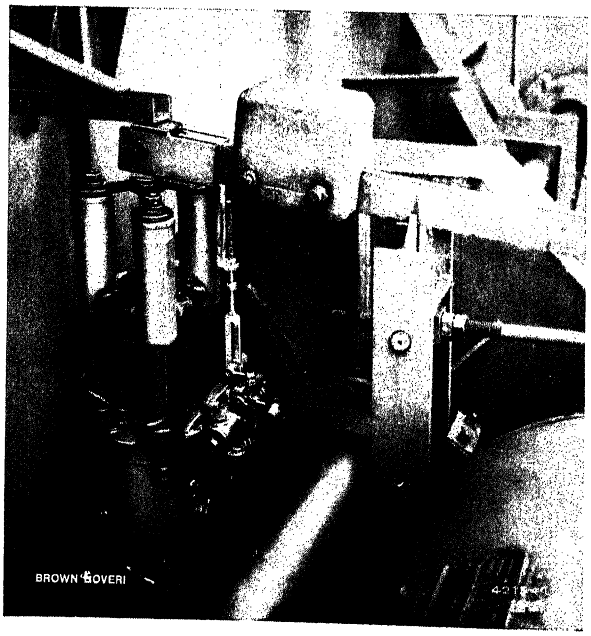

Fig. 1. — Electro-hydraulic thruster, with protection against dust and damping device which can be adjusted, mounted in the high-power hoisting mechanism.

The connection allows of attaining excellent transhipping conditions with a small outlay of power; it permits of having both super- and sub-synchronous braking, so the load can be displaced rapidly over big distances, lowered at any speed desired and braked electrically, before complete stoppage. It should be noted that this connection can be attained very simply with the same apparatus used for ordinary reversing connection, that is a controller, resistance, brake releaser and the interlocking and safety switches necessary. In the present case, on account of the relatively high amounts of power employed, contactor equipment has been widely used. It is worthy of note that, for most of the mechanisms, the electric brakes are not controlled by electro-magnetic brake-releasing devices but by the new electro-hydraulic thruster brought out by Brown Boveri (Fig. 1).

This second truck-tilting machine has been in continuous service since more than one year and, like the first one, has given excellent practical results. The technical personel of the Dutch Railways and the operators running the machine give special praise to the connection for sub-synchronous braking at lowering, which allows of simple and reliable control of all the movements of the equipment.

(MS 527) *G. Rochat. (Mo.)*

A simplification of the automatic regulation of the sets used for the flexible coupling of power systems.

Decimal index 621.314.26 (078).

As is well known, the different converter sets for flexible coupling built, up till to-day, by Brown Boveri — among which those of the Mühleberg[1] and of the Seebach[2] stations are typical examples — permit of regulating the power exchanged between systems, not only to a constant value, but in function of the frequency of one or the other of the two systems connected together. The practical results obtained have been most satisfactory.

However, although maintenance of constant power exchanged only calls for relatively simple regulating organs, regulation of the power exchanged in function of the frequency requires expensive apparatus.

As long as the sets under consideration are of big output, the cost of the said apparatus is not a factor of great importance, but, in the case of relatively small sets, the cost of the apparatus becomes decidedly too high.

Now, regulation of the power exchanged in function of the frequency is, also, very desirable in the case of smaller converting sets, as well, and this for several reasons: — generally, it is desirable to "support" the frequency of the system being supplied by making the converter set supply whatever additional output is required, further when the generator has to operate alone, the object is to dispose of current at constant frequency and, above all, to prevent the generator running away. In the latter case, the generator regulated to give constant load and not having organs for limiting its speed may well run away, just as a turbine would when its

[1] Readers are referred to booklet 1344 E "The Muhleberg Converting Plant."

[2] See the S. E. V. Bulletin, No. 3, 1934.

admission organs are opened full. Some supplementary regulation must, therefore, be provided which operates in function of the frequency of the generator.

A hand-regulating equipment would make too frequent demands on the operators and would not be, really, reliable.

For this reason, a simplified automatic regulation system was developed and in order to grasp its operation the Brown Boveri-Scherbius principle of regulation must be born in mind.

It will be recalled that the power of an induction machine is a function of the e. m. f. induced in its rotor. This power will, therefore, be zero at any moment, *whatever the speed of the machine,* if a means be found to nullify this e. m. f. by an equal and opposite one, of the same frequency. If, now, it is desired that this machine, thus neutralized, should deliver a regulated amount of power, it is sufficient to create a second voltage of proper frequency in the rotor, which can be acted on as required and which alone dictates the new power output of the machine.

The neutralizing e. m. f. is produced by the Scherbius machine; the latter of the commutator type, excited at the slip frequency, delivers a voltage of the same frequency at its brushes.

At the beginning, the connection — termed "Seiz coupling" produced this e. m. f. in the Scherbius machine by means of a shunt excitation tapped on the rotor of the induction machine. But this neutralization was not exact enough and also gave rise to auto-excitation phenomena

It is only by compensating a *fraction* of the e. m. f. of the rotor by this means that it is possible to suppress auto-excitation. The *other part* is suppressed with the help of a so-called no-power regulator.

With the aid of the latter, the e. m. f. in the rotor can, also, be *entirely* suppressed and, thus, the shunt excitation can be dispensed with.

The regulator acts in the following manner:— by definition, the regulator is only in equilibrium when measuring a power equal to zero. As said before, once the e. m. f. of the rotor is nullified, the induction machine absorbs no more power. The regulator is connected in the circuit of the stator. As long as the machine absorbs power, that is to say as long as the e. m. f. of its rotor is not zero, the regulator will be displaced and will act on the excitation of the Scherbius machine (by means of a second intermediary commutator machine also having the slip frequency) until the e. m. f. of the rotor of the induction machine is nullified and, as a result, the power circulating through its stator winding is zero.

From this moment, the rotor of the induction machine can have any slip with respect to the stator field.

All that is, now, necessary in order that the induction machine should supply a given power output is to impress on the rotor a second e. m. f. of suitable magnitude (having also and at every moment the slip frequency). The power will, then, depend on this second voltage alone and the speed may have any value. This second voltage is generated in the Scherbius machine by superimposing a second current, coming from a potentiometer, on the current of the regulator, coming from the stator; as, now, by definition, the regulator must regulate to zero output, the sum of these two currents must be zero. The regulator thus moves and excites the Scherbius machine until the current of the induction machine is equal and opposed to that of the potentiometer. At this moment, the regulator attains the new position of equilibrium. The potentiometer current, thus, dictates the current absorbed by the induction machine, in other words, the power of the set depends on the position of the potentiometer. There is a constant power output for any given position of the potentiometer.

The potentiometer is controlled in function of the frequency of one of the systems when the output of the set is to be in function of the said frequency.

Up till now, electric regulation as a direct function of the frequency had never been carried out and electromechanical organs had to be used (centrifugal regulator driven by electric motor and acting through rods and transmission levers on an automatic potentiometer, in some cases, a dynamo-tachometer rotating synchronously with the pilot system and supplying the motor of the regulator).

Thanks to the frequency regulator which Brown Boveri has just brought out, all these organs can be suppressed. The sectors and resistances of the frequency regulator play the part of a potentiometer. A hand-adjustable knob mounted on the cover of the apparatus allows of adjusting the balanced position of the moving

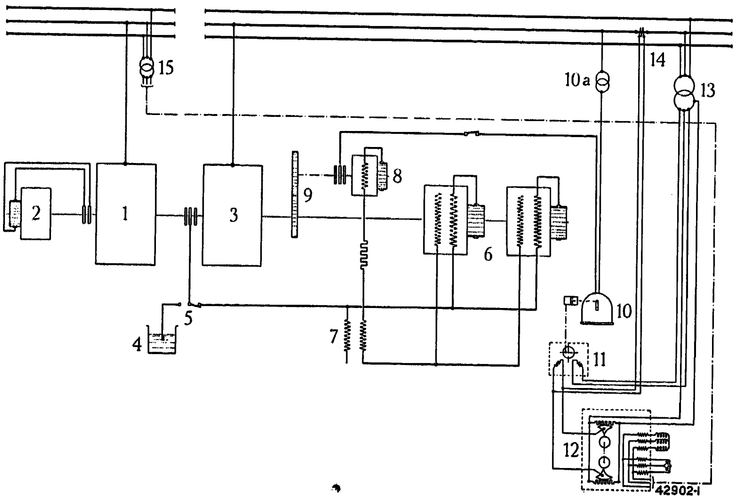

Fig. 1. — Theoretical diagram of connections of a converter set with slip, with automatic regulation of power and frequency.

1. Synchronous generator.
2. Exciter.
3. Synchronous motor.
4. Starter.
5. Change-over switch.
6. Double Scherbius machine.
7. Excitation transformer.
8. Auxiliary excitation machine termed "frequency converter".
9. Small auxiliary gear.
10. Double induction regulator.
10a. Auxiliary transformer.
11. No-power regulator.
12. Frequency regulator.
13 and 15. Voltage transformers.
14. Current transformer.

part dictating a constant power output of the set for a given range of frequency. Usually, the regulator does not move, the set runs at constant-power output; only when the frequency goes beyond the range set, the regulation intervenes to alter the power transmitted. This system of regulation is particularly convenient when the synchronous machine operates alone; its speed does not exceed certain values, whatever the fluctuations of the load.

The frequency regulator is like an automatic voltage regulator of standard design, but has two moving equipments on the same shaft and subjected, one, to an inductive-voltage circuit and, the other, to an opposed capacitive circuit. For a given frequency or for a given range of frequency, the actions of the two circuits on the moving gears compensate one another and the axis takes up a certain position. When the frequency varies more than the range set for, the characteristics ωL and $\frac{1}{\omega C}$ of the two circuits vary in counter sense. If the action of one predominates, the moving equipment moves in corresponding direction and changes the position of the sectors.

The fundamental diagram of connections with Scherbius machine and auxiliary exciter, as well as regulating organs, is shown in Fig. 1.

This simplified regulating system, by frequency regulator has been used, with success, by Brown Boveri, in the flexible 1850-kVA set of Bevers Substation of the Rhetic Power Stations. This set connects the distribution system of the latter works at 50 cycles, with frequency variations between 49·5 and 51·5 cycles, to the system of the Rhetic Railways at $16^2/_3$ cycles, with a frequency variation between 15 and 18 cycles.

(MS 526) *A. Maret. (Mo.)*

The tow-line plant (ski lift) for skiers at St. Moritz (Switzerland).

Decimal index 625. 921. 3 (494).

APART from funiculars and aerial rope ways, several tow-rope plants, known as ski lifts, have been built,

Fig. 2. — Towing gear of the Suvretta Ski Lift, St. Moritz (Switzerland).

quite recently, to allow skiers to reach good practice slopes at high altitudes, rapidly and without exertion. A plant of this kind, on a big scale, was put into service in December 1935; this is the Suvretta (St. Moritz) ski lift, built to the patents and under the supervision of E. Constam, engineer of Zollikon near Zürich, who is the inventor of the tow system used.

The length of the line is 800 m. The difference of altitude between the lower station, where the driving engine is located, and the upper station is 260 m. When fully utilized this line can take up 450 people per hour at a maximum speed of 2·25 m/s. The plant consists of an endless cable, carried by a number of supports located on the slope and round two drums in the terminal stations for changing its sense of direction. There are cleverly-devised hook-shaped rests which allow the traveller to be towed along without danger or effort. The lower of the two cable drums mentioned is driven through a conical gear by a three-phase induction motor of 47-kW rated output at 965 r.p.m., 380 V, 50 cycles. A seven-step controller is used to start the motor and, if necessary, to regulate the towing speed. The haulage machinery is provided with a brake device with electromagnet control, such as are used on cable railways. There is a switchbox with thermal releases to protect the motor drive against overloads; it also cuts out the drive if current fails on the supply system and if the end travel switch at the end of the trip is actuated. This end-travel switch is connected to a cable stretched across the track, which causes the drive to be cut out if a traveller happens to run into the said cable. This

Fig. 1. — Suvretta Ski Lift, St. Moritz (Switzerland).

prevents a skier being drawn into the cable drum, if he runs over the proper end position.

Brown, Boveri & Co., Ltd., Baden (Switzerland), built the electric equipment which met every requirement. Two other plants built to the Constam patent and equipped by the Cie. Electro-Mécanique, Paris, were built in 1935/36 in the French Alps. The carrying capacity of these plants is most remarkable. Thus, the Suvretta plant, described here, carried about 30,000 persons in its first winter season 1935/36.

(MS 531) *E. Hugentobler. (Mo.)*

Feed water for the Velox steam generator.

Decimal index 621.187.12:621.181.65.

In a modern steam power station, the quality of the feed water is a factor of great importance because the properties of the water have considerable influence on both reliability and economic operation of the steam boiler. Based on present-day knowledge, the qualities which must be insisted on for the feed water, whatever the type of boiler, are the following:—

1. It must not form an adherent coating in the boiler.
2. It must not attack any of the materials entering into the construction of the boiler.
3. It must not cause any spurting, foaming or other trouble in the evaporation.

In the competitive struggle between rival boiler types, it has often been asserted that, owing to the high specific heat generation, the Velox steam generator is more liable to suffer from boiler-scale formation than other types of boiler and that the feed water has to meet more stringent demands than is otherwise the case.

These assertions cause Brown Boveri to publish, here, the excellent results attained with a Velox steam power station, which has been running for a long period in a chemical works, and the feed-water properties of which are particularly poor.

The Velox steam generator of this plant produces a maximum quantity of steam of 18,000 kg/h at a pressure of 36 kg/cm^2 abs and a steam temperature of 400° C. This steam is utilized to generate electric power in a back-pressure turbine in which it expands, partly, to be then totally expanded in the course of certain chemical processes. The condensate is not used to feed the Velox. In plants of this kind, the water question is of particular importance, as the boiler has to be fed with 100% of treated raw water. In the present case, this water is as unfavourable in its properties as can well be imagined. It contains silica but is also a soft river water, the analysis of which is given in the accompanying Table I. As the maximum and minimum values of the analysis show, the properties of the water vary, according to the season. Further, the water sometimes holds in suspension a very fine clay sludge, which is distributed so finely in the water that it is a hopeless task to get rid of it by sand filtering. The only way of precipitating it is to treat the water with freshly precipitated aluminium and magnesium hydrooxide. These hydrooxide flakes have the property of absorbing the clay sludge in suspension. A subsequent filtering in a sand filter produces quite clear water. The bicarbonates of the alkaline earth are precipitated by a solution of caustic soda. In this process, a quantity of soda, equivalent to the solution of caustic soda is formed which, in its turn, brings down the permanent hardness. In order to remove, simultaneously, both the hardness and the clay sludge, the raw water is treated in a water purifier with a solution of caustic soda and magnesium sulphate, at 80° C.

The water from this purifier has an average hardness of 0·7—1 German degrees of hardness. (1 British degree of hardness = 0·8 German degrees). In a plant working on the purely condensate method, this water could be used again as make-up water without further treatment. As boiler feed-water alone, however, it could never be used on account of the considerable amount of silica it contains. It must, therefore, be subjected to a second treatment with trisodium phosphate the object

TABLE I.

Raw water, feed water and boiler water for a Velox steam generator with 100% chemically-treated water.

Composition	Raw water (average value)	Raw water (min. and max. values)	Softened raw water after 1 st stage (average value)	Feed water (average value)	Boiler water (average value)
p in ccm n/10 HCl . . .	—	—	0·25	0·4	14·4
m in ccm n/10 HCl . . .	1·7	1·4–3·9	1·65	1·75	16·5
Transitory hardness (German degrees) . .	4·8	3·9–8·1	—	—	—
Permanent hardness (German degrees) . .	1·5	1·1–7·9	—	—	—
Total hardness (German degrees) . . .	6·3	5·0–16·0	0·7	0·1	0·6
CaO in mg/l	—	37 to 118	—	0·1	0·6
MgO „ „	—	10 to 32	—	0	0
Al_2O_3 „ „	—	0 to 1	—	0·2	—
Cl „ „	21·3	21 to 76	—	15·9	170·0
SO_3 „ „	—	13 to 28	—	38·4	391·0
SiO_2 „ „	14·0	12 to 21	—	13·2	117·5
P_2O_5 „ „	—	—	—	2·9	23·5
Caustic Soda figure . . .	—	—	—	—	550

of which is to prevent a silica scale forming in the boiler. The entire raw-water treatment of this plant requires:—

River water

1st purifier with solution of caustic soda and magnesium sulphate. Temperature 80° C.

Sand filter

2nd purifier with trisodium phosphate. Temperature 95° C.

Feed-water tank.

The analysis of the water produced is given in Table I. The water can be considered as having lost its hardness. The hardness varies between a minimum value of 0° and a maximum value of 0·3 German hardness degrees. The amount of blow down of the boiler water attains about 10 % of the feed water quantity injected. The water in the boiler is thus subjected to a tenfold concentration. This increase in concentration, would reinforce the very slight hardness in the boiler which would attain inadmissible values. According to the analysis of the feed water a silica scale formation is, specially to be feared. It must not be forgotten, however, that the phosphate ions are also subjected to a tenfold increase. As the calcium phosphate precipitates at even smaller concentrations than calcium silicate, the hardness is reduced in the form of calcium phosphate flakes and not as calcium silicate scale stones. The former has the quality of absorbing $Si\,O_2$. There is, therefore, a certain counter-silica scale influence at work, which is seen from the fact that the silica does not attain the same concentration as the other salts. The Velox steam generator has been operating for nearly a year with this feed water and giving excellent service. The vaporizing elements are free of all scale formations and no observations show salts being carried along with the steam.

This experience from everyday service shows that the Velox is perfectly suited to work in plants using 100 % treated raw water containing a great deal of silica, just as well as in plants working to the condensation and distilling process.

The danger of scale formations of all kinds is much less in the Velox than in any other type of boiler, because the circulation pump imparts a high water velocity and produces active spraying of the heated surfaces, thanks to appropriate water-circulation design. There are no dead ends favouring deposit formations. The Brown Boveri Velox steam generator can be installed in any steam plant, whatever system of condensation is used; it will increase the economic qualities of the said plant thanks to its own valuable properties.

(MS 532) *J. Biert. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2): 621. 313. 322.

THERE are two Brown Boveri generators running, to-day, in perfect condition, in the Papierfabrik Cham A.-G., Cham (Switzerland), which were delivered in the years 1897 and 1904 respectively and have, thus, seen 40 and 33 years of service.

The first unit carries the shop number 2835. It was delivered as a two-phase alternator with vertical shaft, designed for 260 kVA at 2100 V, 62 A per phase, 87·5 r. p. m., 46·7 cycles. The vertical-shaft exciter is mounted separately and is driven through conical gear wheels from the generator. It runs at 450 r. p. m. The second generator, delivered in the year 1904, was also wound for two-phase A. C. current; it is of vertical-shaft design, as well, being built for 260 kVA, 2100 V, 62 A, 127 r. p. m., 46·7 cycles. The exciter runs separately.

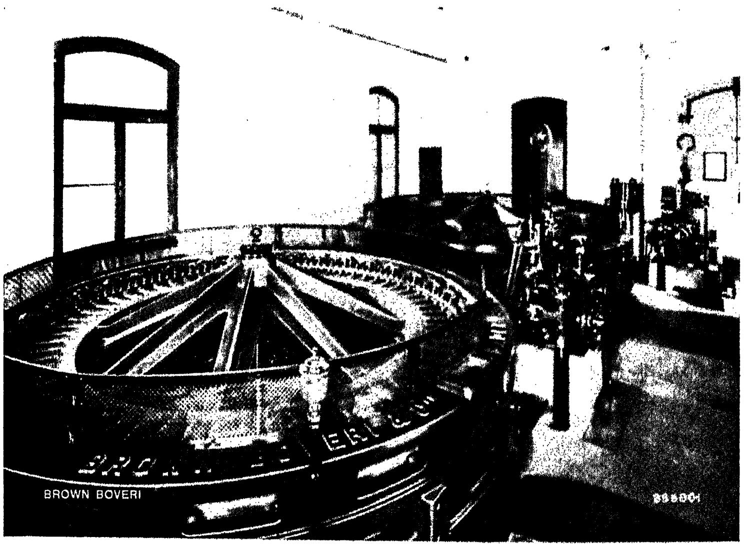

Fig. 1. Papierfabrik Cham A.-G., Cham (Switzerland).
Two three-phase generators delivered in 1897 and 1904, respectively.

To-day, both generators work at 50 cycles and 2250 V and their speeds have been increased to 94 and 136 r. p. m. respectively, to meet this higher frequency. Except on Sundays, these units run day and night and, in spite of their many years of service, have never required major repairs or extensive overhauling.

(MS 501) *Prop.*

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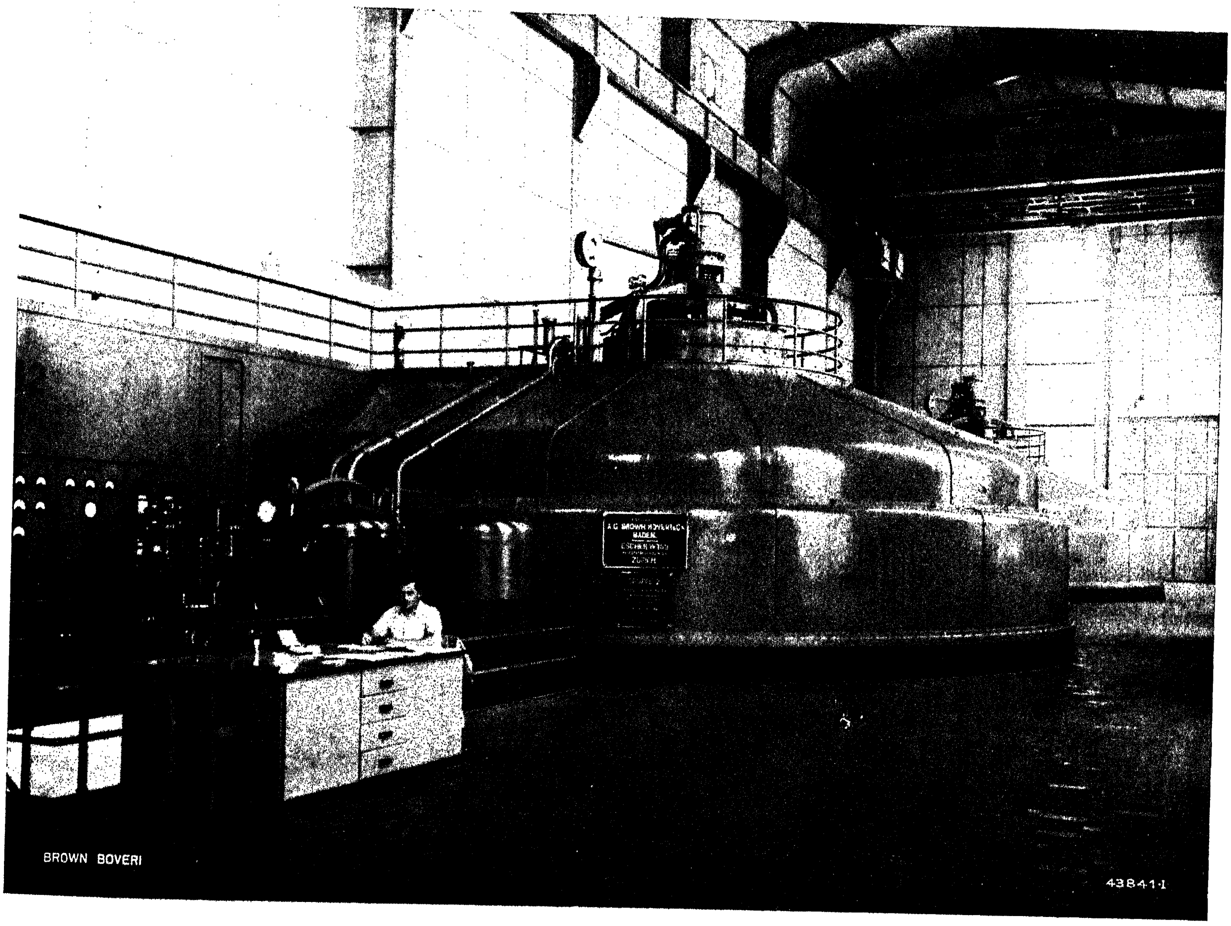

AAREWERKE A.-G., AARAU (SWITZERLAND). KLINGNAU POWER STATION.
Partial view of machine hall showing two of the three-phase generators installed, each of 19,500 kVA, 10,500 V, 75 r.p.m., 50 cycles.

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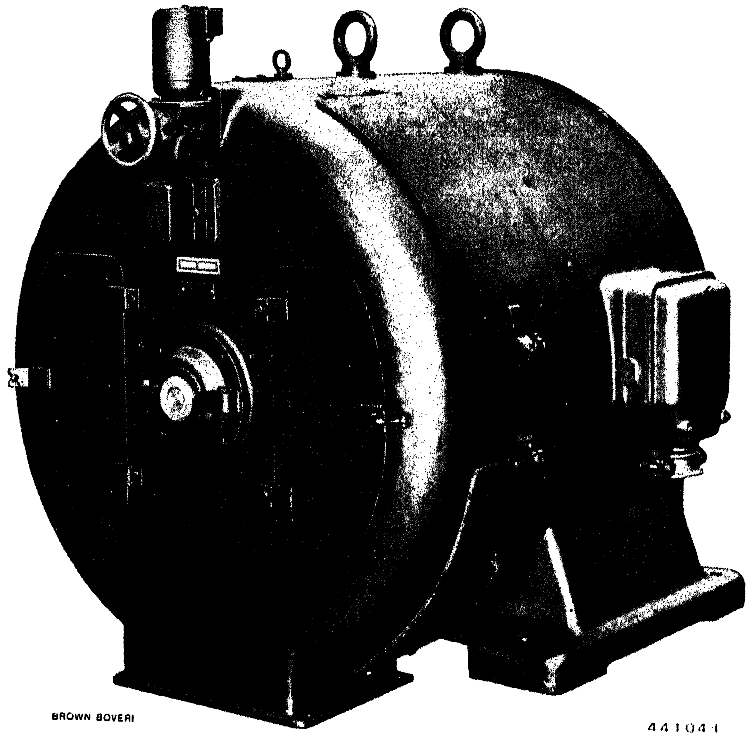
BROWN BOVERI
THREE-PHASE SHUNT
COMMUTATOR MOTOR



for

drives with smooth speed regulation over a wide range
without losses

Speed unaffected by load fluctuations

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIV MAY, 1937 No. 5

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NEW MOTOR COACHES OF THE SOCIETÀ TRAZIONE ELETTRICA LOMBARDA, MILAN.

Decimal index 625.62:621.335.4 (45).

THE Società Trazione Elettrica Lombarda (STEL) put six new motor coaches into service, in March 1936, which run between Milan and suburban localities of that city.

The bogies and electric equipment were ordered from Tecnomasio Italiano Brown Boveri, Milan, while the coach bodies were built by the Officine della Società Ernesto Breda in Sesto S. Giovanni. On account of certain pronounced characteristics of the traffic conditions on the lines in question, the coaches have two objects to fulfil:— during hours of peak traffic, they must run with one or two trailers, while running alone when traffic is light. Under both conditions, they must attain high schedule speeds and offer every comfort to passengers.

Each motor coach was equipped with four driving motors of relatively high one-hour output rating and which could carry heavy overloads. These units had to be designed for automatic control, especially at starting. The control allows the driver to chose any one of six acceleration values. According to the composition of the train and to traffic conditions on the road, he can accelerate uniformly up to the highest acceleration figure which has ever been practically attained, in Italy, up till to-day.

Further, the bogies used on these coaches are of an improved design which is specially characterized by noiseless running, great stability and smooth travelling at the highest speeds.

The following are the characteristics of the coach (Figs. 1 and 2):—

Length of coach body	14,500 mm
Max. length over buffers	15,200 ,,
Max. width of coach body . . .	2340 ,,
Distance apart of bogie pivot centres	7750 ,,
Wheel base of bogie	1800 ,,
Max. height of roof above rail surface	3350 ,,
Clearance of coach floor over rail surface	970 ,,
Diameter of wheel	760 ,,
Number of driving motors	4
One-hour rating of each motor . .	56·5 H.P.

at 1130 r.p.m., 550/2 V, 175 A.

Weights:—

Coach body	about	11,280 kg
Door-closing gear	,,	500 ,,
Bogies	,,	5270 ,,
Electric equipment (four motors)	,,	2760 ,,
Remainder	,,	1190 ,,
Total, motor coach empty .	,,	22,000 kg.

Number of passengers, seated . . .	41
Number of passengers, standing . . .	80
Highest speed on the level	60 km/h.

1. *The coach body.*—The structure proper of the coach is entirely of tubular elements and forms a single, strong girder. The different metallic connection parts are held together by rivets and the whole framework design is such that the static stressing does not exceed 5 kg/mm^2.

The coach (Fig. 1) is built to run in both directions. It is symmetrically subdivided into a central and two end compartments. The doors are located at the two ends, passengers entering at the back and leaving at the front. Tickets are taken during the trips after entering the coach, the rear driving cab being used as a conductor compartment. The seats have folding backs and hold two passengers, on one side and one passenger on the other side of the coach, leaving a gangway between, to facilitate the movement of the public from the back towards the exit at the front.

The doors are operated electro-pneumatically by The National Pneumatic Company's well-known patented door-closing device, built in Italy by Tecnomasio Italiano Brown Boveri.

The doors and the folding step are operated through a small compressed-air motor for constant

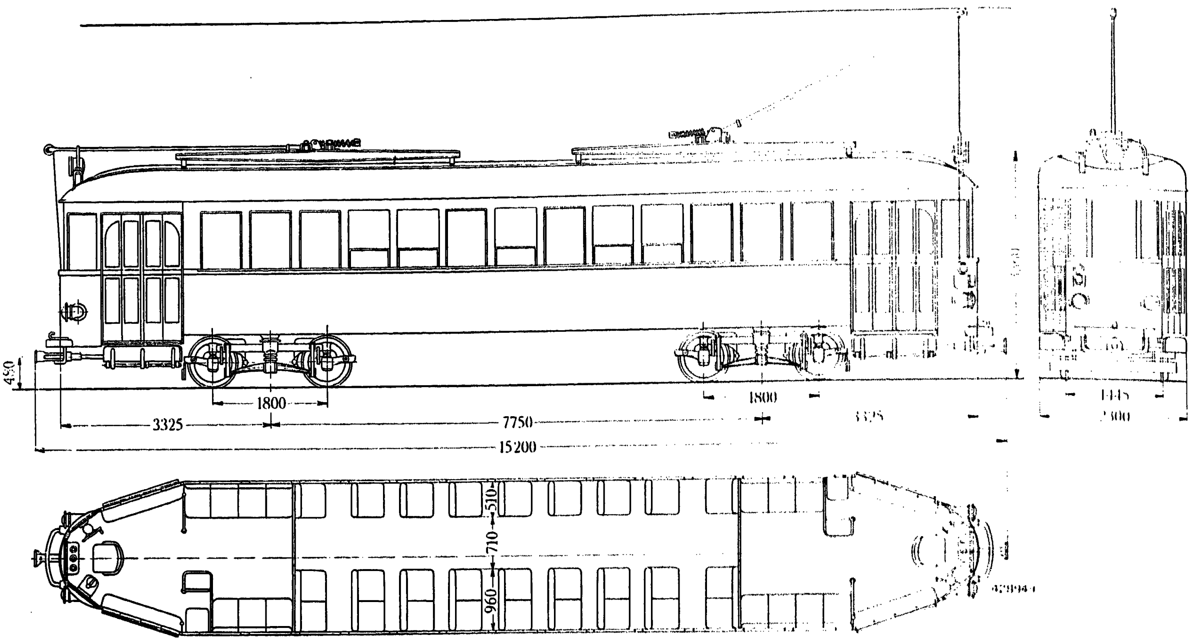

Fig. 1. — General drawing of motor coach of the Società Trazione Elettrica Lombarda, Milan.

speed, independent of the compressed air in the container tank. Dangerous banging of the door wings is prevented in case a traveller might chance to be just in the doorway at the moment of closing.

The control over the pneumatically-operated door-closing gear is electrical and carried out with the help of electro-pneumatic valves, located beside the operating apparatus and controlled by switches. These can be worked either by the driver or the ticket collector.

The door-closing gear is locked when the coach is started in such a manner that the latter can only start when all doors are closed, and further the supply current to the motors is cut off if one of the doors should happen to be opened accidentally when the coach is running.

Great care was paid to ventilation, a matter of importance at times of heavy traffic.

There are eight electric heaters built into each coach, each for 600 watts.

2. *The bogies.*- The coach body rests on two bogies of the Brill 84 E design which has, already, given proof of its qualities in most satisfactory trial runs in America.

The numerous improvements incorporated in this type of bogie result in silent and smooth running. The bogie bolster is guided by a pivoted arm which allows the bolster free, sprung displacement both in the vertical and the cross sense, but prevents longitudinal displacements. Further it was found feasible to eliminate axle bearing guides (horn plates), thanks to a patented construction of mobile axle boxes. The axle box carries a forked cast-steel arm (Fig. 3) which is pivoted on the main frame of the bogie by means of a pin, and round which fulcrum the axle box can move. Thus, the forces set up

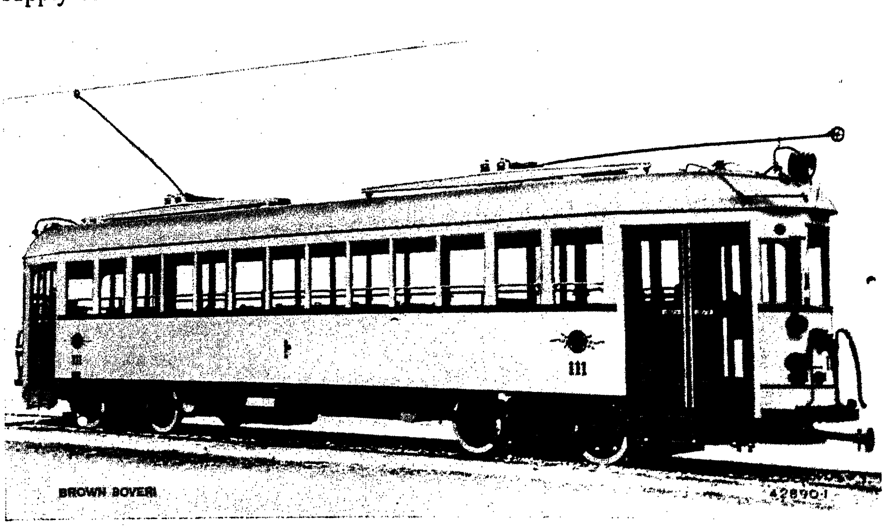

Fig. 2. — View of motor coach.

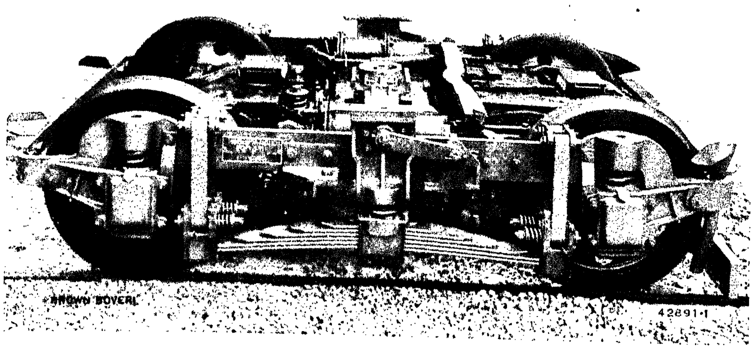

Fig. 3. — Bogie.

at starting and braking are transmitted from the wheel set to the bogie frame through the pivoted arm of the axle box, this without shocks or noise.

A further advantage of the said flexible axle-box guide is that the clearance between brake blocks and wheel tires, is maintained constant independently of the load of the coach. Thus, by suitable choice of fulcrum point of the axle-box arm and of suspension point of the brake shoes, a sinking of the brake shoes caused by a bigger coach load results in an equivalent reduction of bogie-wheel base.

The coach is sprung on three systems of springs:— two with helical and one with laminated springs. A first system of helical springs (each composed of three concentric springs) is located between the upper part of the axle box and the sole bar of the bogie, it is held in a cup on the bogie frame. The second system consists of a laminated spring on each side of the bogie; the bolster rests on the middle point of this spring, the spring, itself, being suspended at both ends by link hangers to the sole bar of the bogie. The third system consists of helical springs inserted between the bottom side of the bolster and the top side of the laminated spring, the duty of this system is to spring the bogie when the coach is empty or carrying a light load. The first two spring systems would be too hard for such cases. The effect of the last mentioned system of springs is eliminated when the load of the coach exceeds half the full-load value. The two first systems come into play and are sufficiently soft, in such cases, to assure smooth running.

A further essential characteristic of the bogie, Type 84 E is its damping systems against cross oscillations. It is composed of special dampers lodged in the connection points of the laminated springs and the link hangers (Fig. 3).

To eliminate metallic noises, there are rubber pads under the bogie socket and under the sockets of the lateral supports as well as under the axle box springs; these break the metallic connection between coach body and bogies.

The brake equipment consists of two cylinders each of six inches bore on each bogie. Thus, the majority of brake rods has been eliminated, as these are always the seat of noise and demand considerable upkeep. Finally, the bogies have automatic brake-play adjustment devices of the Brill system which allows of wearing down the whole brake shoe without it being necessary to make adjustments by hand to pick up the play due to wear.

3. *Electrical equipment.*—Of the four driving motors, two are always connected in series. Each motor is series-wound, having four main and four auxiliary poles, and is built for a one-hour rating of 56·5 H. P., 550/2 V, 1130 r. p. m. The continuous rating is 42 H. P. at 550/2 V, 1250 r. p. m. (Fig. 4). The housing is in one piece and roller bearings are fitted. During running, these motors can be considerably overloaded, up to double the one-hour rating output.

The automatic apparatus consists of a combination switch (Fig. 5) lodged under the coach. This is controlled by a servo-motor which works with compressed air and is remote-operated electrically by means of a control switch in the driver's cab. This switch is actuated by the seated driver through the agency of a pedal.

The pedal positions are:—

1st position = Shunting position. All motors in series with all the starting resistances.

2nd position = Starting the coach up to short-circuiting of all the resistances, with all motors in series, low acceleration.

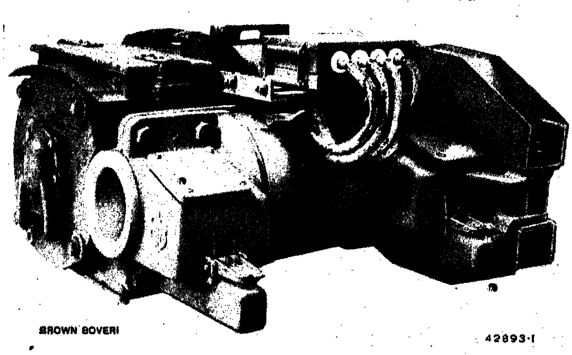

Fig. 4. — Traction motor.

3rd position = Starting period until all resistances are cut out and the motors are series-parallel connected; low acceleration.

4th position = As pos. 3:— average acceleration.

5th position = As pos. 3:— high acceleration.

The various combinations of the motors and the different acceleration values during starting, corresponding to the five positions just enumerated, are attained by closing certain electric circuits which result in the automatic displacement of the main combination switch. The latter is composed of a set of apparatus in a common housing, the duty of which is to carry out the cutting out of the resistances and switching over of the motors during the starting period and this entirely automatically and in relation with the strength of the motor current taken, operations being supervised by an acceleration relay with a variable adjustment.

It was thought preferable to make the control of the combination switch by compressed air as it is a flexible medium which does not transmit shocks, as compared to other mediums, hydraulic systems for example, where changes in the viscosity of the fluid with the temperature means constant variations of the adjustment. Systems with an electrically-controlled servo-motor, also, do not appear suitable for a control of this kind as they are always at the mercy of unavoidable voltage failures on the trolley wire.

The compressed air servo-motor, patent Tecnomasio Italiano Brown Boveri, Type PAV, to actuate the combination switch, is composed of a cylinder containing two pistons coupled by a rack rod. This rod actuates a pinion keyed on the shaft of the combination switch. The movement of the rack rod is controlled by two electro-pneumatic valves. These are excited or cut out by the pedal-operated switch, from the driver's cab; the switching-on valve being, however, under the control of the acceleration relay.

The simultaneous excitation of both electro-pneumatic valves produces a difference in pressure between the two sides of the cylinder. The pistons move in one direction and the rack drives the shaft of the combination switch to which are secured the cam discs to actuate the individual cam switches. The switching process is supervised by the acceleration relay which causes, automatically, the stopping or moving on of the combination switch, according to the magnitude of the current absorbed by the traction motors. As a result, the combination switch only carries out the transition from one position to another when the current taken has attained the desired strength; thus, the motors are never exposed to excessive current surges.

On account of the small angle of rotation between the individual steps, it is essential that the shaft of the combination switch should be maintained exactly in the successive positions it occupies as it moves over and that there should be no possibility of the switch stopping between steps. This exactitude in position is arrived at pneumatically and electro-pneumatically, in the following way:—

If the acceleration relay acts, it causes the holding relay (Fig. 5) to be excited. This relay, however only acts when the shaft of the combination switch has attained a certain position which is done with the help of the auxiliary contacts which run on the contact cylinder which is on the front side of the servo-motor. The holding relay opens the circuit of the electro-pneumatic valve to switching on, by establishing the same pressure on both sides of the cylinder and by, simultaneously, closing the circuit of a locking relay which designates exactly the position of the shaft of the combination switch with the help of a moving armature which meshes in the corresponding slot of a cam disc.

If the current taken by the motors falls, the acceleration relay breaks the circuit of the excitation current of the holding relay, which then, again, causes the circuit of the electro-magnetic valve for forward switching to close and breaks the circuit of the locking relay. The combination switch then moves forward by one step. The cutting-out of the resistances is looked after by cam-controlled contactors. The passage from series to series-parallel connection of the driving motors is carried out by three remote-controlled contactors placed on one side of the controller (Fig. 5) and the circuit of which is locked by auxiliary contacts so that switching over is automatic and takes place in the proper sequence.

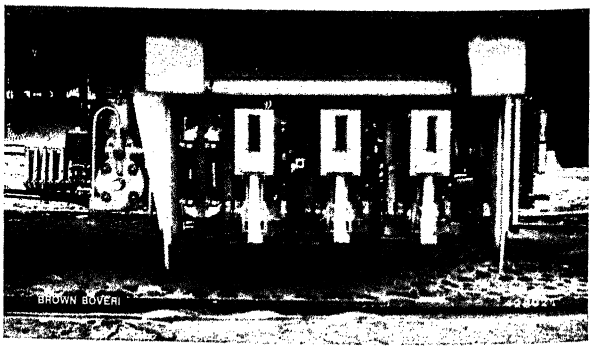

Fig. 5. — Combination switch.

Further, the automatic equipment for starting is so designed that different values for starting acceleration can be adjusted to, this in order to allow the driver to accommodate the traction force to the load of the train or to the traffic conditions on the street. The different starting acceleration values are obtained by means of the pedal controller and by a switch actuated from the driver's seat which allows of altering the adjustment of the acceleration relay. Apart from the current coil through which the supply current of the motors flows, this relay has also got a voltage coil which produces a field in the same sense as the first coil and which can be fed with different current strengths according to the position of the pedal, or of the switch in the driver's cab.

It is obvious that the acceleration relay requires a definite total field to cause it to act. If the field of the voltage coil is low, due to lower current through this coil, the field produced by the current coil must be greater to compensate it and the main current which causes the relay to act must be stronger. If the current through the voltage coil is increased, the acceleration relay will act for lower values of the current coil ampere turns, i. e. for lower values of the main traction current. The excitation of the voltage coil with various voltage is taken care of by a potentiometer inside the main combination switch.

In this way, it was possible to obtain six different acceleration values at starting, which can be used according to the composition of the train: — motor coach alone, with one trailer, with two trailers.

At the maximum starting acceleration, the motors develop an average traction effort of about 4700 kg when the motor coach is alone and carrying medium load, they allow an acceleration of 1·75 m/s². The minimum acceleration, under the same conditions, is about 0·58 m/s². The maximum acceleration of the empty coach alone is 2 m/s².

It has been found that the disagreable repercursions on the travellers at starting is due, less to the acceleration proper, than to variation in the acceleration. Recent investigations in America carried out at the instigation of the Electric Railway President's Conference Committee showed that the allowable limit value of acceleration variation in horizontal sense should not exceed 2·12 m/s³ per/s. This is the maximum figure which standing passengers can be exposed to. Although this figure was applied in trial runs with two trial coaches of President Car type, the acceleration variation figure of 1 m/s³ per second was chosen in the present case, as a maximum for the new STEL motor coaches, in order that starting should be gradual and not inconvenience passengers. The speed time and displacement time curves of Fig. 6 make these properties clear.

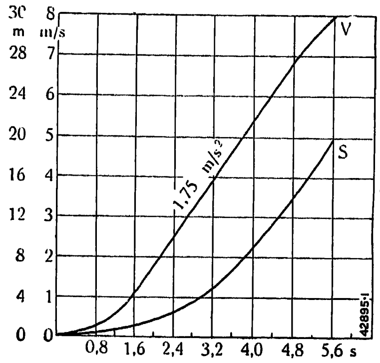

Fig. 6. — Displacement/time and speed/time curves.

The bend of the speed curve over the time grows gradually; finally, the curve becomes a straight line corresponding to the maximum value of 1·75 m/s².

The simplified general diagram of connections of the motor coach is given in Fig. 7. There is the possibility of braking electrically (short-circuit braking) in an emergency. The arrangement of the motors, with two units always in series, gives a terminal voltage per motor corresponding to half the value of the trolley wire voltage, which has the advantage of reducing the voltage per commutator segment.

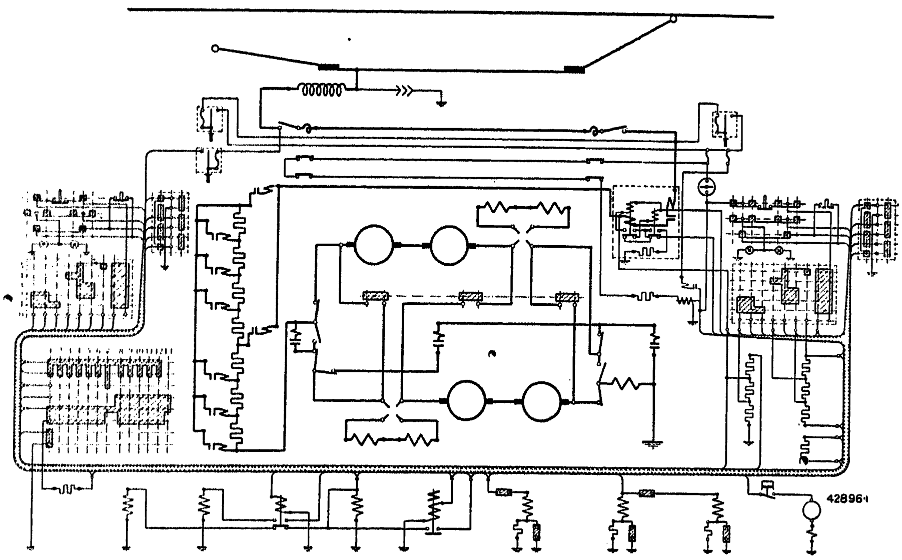

Fig. 7. — Diagram of connections of motor coach.

The main driving current circuit is broken by means of a single main contactor designed to handle the highest possible value of the current. This contactor is also operated by a pedal switch from the driver's cab.

When the main control pedal is depressed to the first position, the main contactor is closed, as well as the by-pass contactor. In this way, the traction-current circuit is closed without the main combination switch moving. Thus, if it happens that air pressure is not available or if the motor of the combination switch develops a defect, it is possible to continue to drive the motor coach, to the next depot, for example.

All auxiliary circuits are supplied at 80 V from a tapping on the potentiometer. Its resistance is of chrome-nickel steel wire in porcelain tubes.

The motor coaches described have been put to work on the Milan-Sesto S. Giovanni line, which is 7 km long with stops every 300 m. The Milan-Sesto Cancelli run takes 23 min at 18·2 km/h schedule speed.

(MS 518) *E. Schroeder. (Mo.)*

A DEMONSTRATION PANEL FOR REGULATORS.

Decimal index 621.316.7:606.4.

MORE than 30 years ago, Brown Boveri took up the manufacture of automatic regulators. The first of these, built on the Aichele system and designed specially for the electric-lighting system of railway coaches, comprised a field rheostat actuated by a small motor; the construction of this regulator was rather complicated; nevertheless most of these regulators are still in service, to-day, on passenger and postal coaches. Some years later, in 1909, Brown Boveri brought out a new apparatus, primarily intended for train-lighting systems, as well, but which, even in its first year, found useful application on stationary machines. This is the *regulator with rolling contacts* built to *the Guttinger principle.* At the time it was brought out, the only known regulators were, either, those with vibrating contacts, which act by short-circuiting and inserting, periodically, the field rheostat and which represented the quick-acting regulator proper, or else, the rheostatic apparatus with servo-motor which responded relatively sluggishly and of which the old Thury regulator is, certainly, the best-known example. Thus, the Brown Boveri regulator on the Guttinger principle was a real revolutionary innovation in the field of regulation as it was the first apparatus in which the measuring organ acted directly on the field rheostat of the machine to be regulated, a solution made practically possible by the suitable arrangement of the rolling contacts. Thanks to the very ingenious device used for the damping and elastic-recall system, this apparatus incorporated all the qualities expected of a quick-acting regulator while having a number of accessory advantages such as:— no organs subjected to wear or requiring readjustment and, therefore, no upkeep; simple and stout design which does not demand the intervention of a specialist to put it into service; absolutely reliable working; great adaptability, etc.

At first, the Brown Boveri regulator met with great opposition from the makers of regulators with vibrating contacts, who claimed that their regulators acted quicker. However, practical experience soon showed that the rapidity of regulation of a good regulator does not, practically, depend on the displacement speed of the contacts but on the degree to which the regulator can over-excite, rapidly and powerfully, in order to overcome the magnetic inertia of the machines. From this point of view, the Brown Boveri regulator gave about the same results as those with vibrating contacts for low- and average-power machines while, for more powerful units, its regulating speed was considerably higher.

The great superiority of the Brown Boveri regulator, as regards upkeep and reliability, resulted in the regulators with vibrating contacts loosing more and more ground, this despite all the subsequent improvements made by their makers in these regulators. These regulators are, practically, only used to-day by old-fashioned service men, who are ignorant of any other regulator system and have never had the opportunity of appreciating the qualities of the Brown Boveri regulator.

The regulators with servo-motor of the Thury system have not been widely used, on account of their regulating speed being too low; the same applies to regulators with oil-pressure servo-motors which were put on the market somewhat later and which did not meet with much success. It was fairly ob-

vious that it was not logical to make use of an oil-pressure servo-motor, that is a device which is, inherently, rather complicated, when it was quite feasible to make the mobile system of the regulator act directly on the regulating organ. Oil-pressure should be used only for regulating very high power machines working under conditions which are unfavourable to regulation (operating under-excited, use of a pilot exciter, etc.) that is to say for cases in which it is impossible to use direct control of the regulating organ.

To conclude, it should be said that, in recent years, certain regulators have been put on the market which are composed of a rheostatic regulator operating relatively slowly and the elements of a vibrating-contact regulator to correct the peak values of voltage fluctuation due to big variations in the load. These regulators, as well, did not meet with success, indeed they were found to be the cause of serious trouble and had to be replaced.

When the patents protecting the Brown Boveri regulator became common property, attempts were made to imitate the design of the latter. After the numerous, different regulator systems tried out, this is, surely, the best proof that the Brown Boveri regulator is based on the right principle. Brown Boveri have 30 years of experience in this field behind them and have thousands of apparatus in service to base their conclusions on. Such experience cannot be gained from one day to another, and many qualities which a new type of apparatus is asserted to possess only mask vital weaknesses which do not escape the trained judgment of the specialist.

The first practical applications of Brown Boveri regulators, i. e. to train-lighting and voltage regulation are still the most important fields of utilization today. The voltage regulator is not only used for D. C. and A. C. generator regulation of all sizes and any characteristics but also for converter sets and synchronous phase-compensators; the regulation may be set to constant voltage or to variable voltage according to some determined law, such, for example, as the compensation of voltage drop on a transmission line. For low outputs the regulator can also be used straight in the main circuit as an additional resistance. The Brown Boveri regulator is particularly suitable to parallel operation and this was one of the causes of its enormous success. According to service conditions, the voltage can be maintained absolutely constant or be made to adapt itself to that of a more powerful system, operating in parallel, or it can be compounded in function of the output.

On this subject, it is interesting to note that a recent American technical article prophesies the coming of individual regulation because it is much more advantageous than common regulation and describes different stabilization connections, which Brown Boveri have actually been using, successfully, for more than 25 years!

On the basis of experience gained with the first voltage regulators, it was soon recognized that the principle applied in the said regulators had many other applications. Thus, current regulators were brought out for D. C. and A. C. to maintain the current delivered by a generator in parallel at a constant value, wattmetric regulators to keep the power delivered or absorbed by a converter set at a constant value and, finally, power-factor regulators to regulate the power factor of a synchronous machine or of a plant to a constant figure, such as 1 or 0·8, etc., for example.

The Brown Boveri regulator, later, found a wide field of application as a current-limiting regulator, to protect synchronous machines against overloads and short circuits.

In order to be able to use the Brown Boveri regulator for *intermittent regulation*, as well, that is to say in cases for which it is not necessary to vary a regulating resistance progressively, but to give current impulses for varying lengths of time, a special design was created:— the same mobile system is made use of but the contact sectors and the resistances are replaced by two contacts operated by the mobile system of the regulator. This impulsion regulator or "control relay" can be used like a standard regulator, for a variety of objects:— as a voltage or a power-factor regulator for controlling step switches, for induction regulators, as a wattmetric relay for regulating the output of steam turbines or hydraulic turbines working in parallel on a system, etc. In a general way, the control relay allows of solving exactly the same problems as the regulator with rolling contacts, in the case of an impulse regulation instead of a continuous regulation and this both for D. C. and for A. C.

Thus, for example, in the case of regulation of electric furnaces or of wood-pulp grinders, etc., the electric magnitude has to regulate the flow of a liquid, oil or water under pressure, that is to say, through a regulating valve. In this case, either a standard regulator can be used, which acts on a rotating electromagnet, or else a variation of the standard regulator, the *valve regulator*. This latter has a standard mobile

system and the axle thereof acts on the regulating valve direct through an excentric, the second solution is the one used most frequently.

Another field of application of Brown Boveri regulators which, however, is not a regulation proper, is that of the *automatic paralleling of synchronous machines.* By using the rolling sectors, operated by a motor system, which controls the relative position of the vectors of the two respective voltages to act on a temporized relay, an apparatus is created which allows of automatic paralleling and having not only the well-known advantages of bright coupling but being far more precise than dark coupling. This apparatus, put on the market twenty years ago, rapidly met with success in power- and substations having synchronous machinery and also, especially, in linking-up substations in which it is, usually, impossible to influence the frequency of the systems being paralleled and where the possibility of paralleling is rather a matter of chance. The automatic synchronizer was completed some years later by an automatic frequency matcher composed, in principle, of a synchronoscope working a contact device. The latter acts, in turn, on the regulating device of the speed of the machine driving the alternator to be paralleled, this by rotating the motor in one sense or the other. The impulsions are the more frequent the greater the speed deviation, so that paralleling is attained very speedily.

It is, chiefly, thanks to this entirely automatic paralleling device, allowing of synchronizing and closing of the breakers of synchronous machines of all outputs, that is due the growth in the number of automatic power stations equipped with synchronous alternators, within recent years.

In the paper-making industry, the Brown Boveri regulator found a ready field of application, from the first, to maintain the voltage of the Ward-Leonard generators constant or that of the exciters and also as a speed regulator to keep constant the manufacturing speed. Later on, this regulator found a new application as a so-called draw regulator, in the sectional drive of paper-making machines. It regulates the speed of the driving motors of the different sections in such a way as to maintain the tension in the paper absolutely constant between two adjacent sections. A similar field is offered by multi-motor rolling mills.

The frequency regulator is the latest addition to the automatic regulator family. It can be built either with rolling sectors for influencing the excitation of a machine or as control relay for impulse regulations and, finally, as valve regulator to act on an oil-pressure servo-motor. This regulator has already been widely used not only to regulate the frequency or speed of converter sets and motors, in general, where great precision is required, but also to hold the frequency of whole systems constant and to contribute, along with power regulators, towards the attainement of the most advantageous load distribution between the various generating stations.

Simultaneously with the application of the regulator to the most varied regulating problems, the rolling-contact apparatus series has been completed so as to have a suitable apparatus for every size of machine, that is for every excitation output. Thus, the first standard regulator with two rolling sectors was followed by one with four, for bigger excitation outputs. In recent years, a high-power regulator has been added to the series, working with oil under pressure and used for very big machines, and chiefly for those generators in which a main exciter is excited by a pilot exciter. Another type developed is a simplified regulator with one sector for low-power generators.

The primary design of the Brown Boveri regulator has, thus, been completed by a large number of variations always based on the same principle, or else using all the same organs or part thereof. Thus Brown Boveri are in a position to solve every regulation problem put before them and put forward the most suitable apparatus and the most appropriate solution.

On account of the number of models, persons not specialized in regulating problems may encounter some difficulty in choice. This difficulty could be surmounted by putting up a kind of permanent exhibition of existing types or else by showing interested parties those regulators being built or on test. This latter scheme is inconvenient and the permanent exhibition does not in itself allow of making clear demonstrations of how the different apparatus work.

These were the reasons which caused Brown, Boveri & Co., Ltd. to put up a *permanent demonstration panel* in their apparatus shop carrying the most interesting types of automatic regulators. This panel allows of demonstrating the actual operation of the regulators and it also permits of showing how the regulators are put into service and the usual phenomena to be expected with machines which are not of standard type or when exceptional service conditions are met with. Thus, this panel should render signal service for demonstrations carried out before those clients who have special regulating pro-

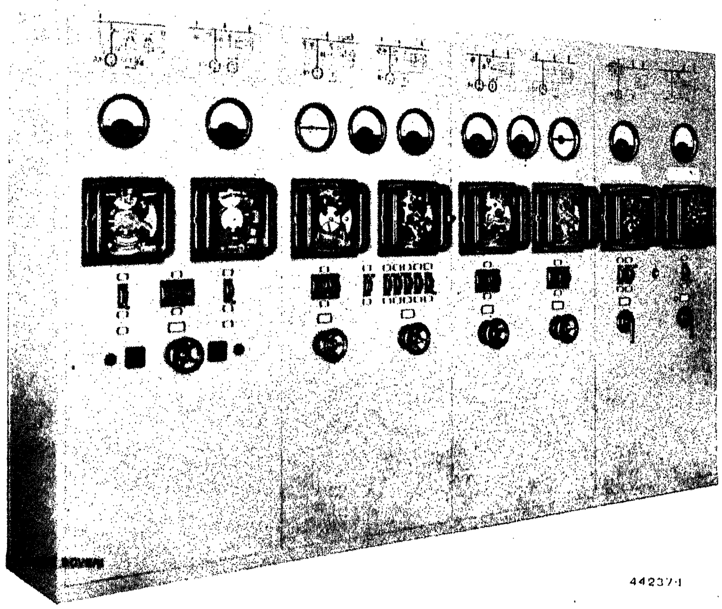

Fig. 1. Demonstration panel for automatic regulators.

blems to solve. It is also useful for familiarizing agents and erectors with this type of apparatus.

Fig. 1 shows the permanent exhibition panel of automatic regulators. From left to right, the following apparatus, which can be shown in action, is clearly seen:—

1 automatic synchronizer Type PB 2/1
1 automatic frequency matcher Type S 2
1 draw regulator Type H 2
1 quick-acting voltage regulator Type AB 2/1
1 automatic frequency regulator Type AB 2/1
1 power-factor and reactive-power regulator Type AB 2/1.

Finally, 2 impulse-type regulators (control relays):—

1 power regulator Type PB 2/1
1 frequency regulator Type PB 2/1.

The exhibition also includes some apparatus identical to that on the panel but of other dimensions, such as a regulator with 4 sectors and the simplified J 1/1 type, as well as a valve regulator Type C.

The combined working of three apparatus on the panel (voltage regulator, frequency matcher and automatic synchronizer) allows of a very realistic reproduction of the most important period as regards switching operations, in the working of an *automatic power station*, namely:— starting up, synchronization, putting under load. The standard service of an automatic power station, that is temperature control of bearings, etc., as well as stopping do not cause any difficulty and are not worth reproducing, here. The panel has, thus, been designed to be considered as being a small automatic power station. It is true that the use of a hydraulic turbine to drive the alternator would have been more close to actual conditions, encountered in practice, this, however, and the laying down of the necessary water piping at the site chosen for the panel would have been rather complicated. As D.C. is available, a D.C. motor was used to drive the alternator, so that the set comprises a three-phase alternator 6 kVA, 1500 r. p. m., 380 V, 50 cycles and a shunt motor of suitable size to drive it. D.C. for the driving motor allows of a very faithful reproduction of the working conditions of a hydraulic station; the motor represents the hydraulic turbine and the field rheostat with motor drive represents the speed governor with its motor for speed variation. Instead of acting on the

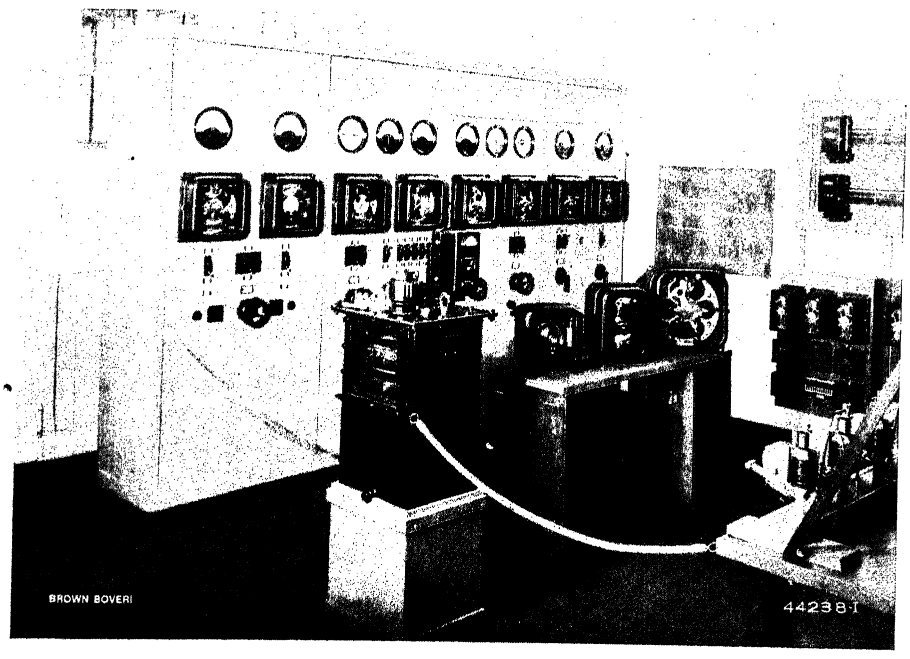

Fig. 2. — Part view of the demonstration plant for regulators and relays.

turbine governor to alter the speed of the set, when synchronizing or when regulating the load, the field rheostat of the motor is moved. It is also possible to drive the generator by a three-phase commutator motor, speed being then varied by brush displacement.

In normal practice, of course, the machines are considerably more powerful and experience proves that it is difficult to reproduce exactly with small sets the conditions met with; the moments of inertia of the small sets being low they are subjected to far more pronounced speed fluctuations than the big units met with in practice. In the present case, however, an alternator was used which had been built for another object. The dimensions of the machine are rather too big for the power generated and the moment of inertia is, also, higher; thus, conditions are closer to those generally met with than would otherwise be the case.

The alternator can either operate alone delivering its power to a load rheostat or else it can run in parallel with the Baden power-supply system. The conditions of a small power station running in parallel with a much more powerful system can, thus, be imitated. A complete set of measuring instruments allows of controlling the operation of the various regulators. Further, the general working diagram of each regulator is reproduced on the upper section of the panel to make the demonstrations easy to follow.

Figs. 3a to 3h give these general diagrams, the machines and instruments being used for the demonstration being carried out are shown in each of the figures.

The most important of the apparatus in the panel is the fourth regulator from the left, that is the *quick-acting voltage regulator* with rolling contacts, of standard two-sector design, Type AB 2/1.

The operation of the voltage regulator can be demonstrated either when the alternator works alone (Fig. 3c) or in parallel (Fig. 3d). In the first case, the load of an alternator depends on what the system supplied can take, a load rheostat allows of reproducing conditions met with in practice. In parallel operation, on the contrary, the alternator load depends on the turbine admission or on the machine driving the alternator, at least in the case of a small machine the speed governor of which is sufficiently static. Therefore, to influence the alternator load when it is in parallel with the Baden system, its motor is acted on and the conditions under which the voltage regulator has to intervene are reproduced with great fidelity.

The principle and design of the Brown Boveri voltage regulator can be assumed here as being generally known; they are the object of special descriptions and of booklets and will, therefore, not be gone into again in the present article. We would, however, recall that the voltage regulator can be subjected to the supplementary influence of current and that the said influence differs entirely according to the phase from which the current is taken. Allowing that the voltage circuit is connected to phases R-S and that the phase sequence is R-S-T, the current of one of the three phases can be used according to what object is pursued. The current of phase R is used to compensate the static characteristic, that is to say for stabilization in parallel operation. On the contrary, the current of phase S is used to compound, that is to increase the voltage in proportion to the load, this to compensate the voltage drop in a transmission line. Finally, phase T is used to stabilize astatic regulators, by means of the polygone connection. According to service conditions, it is often

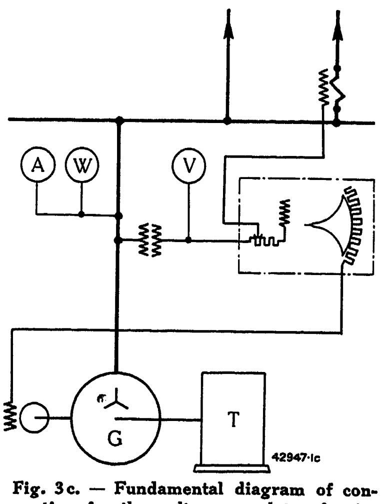

Fig. 3c. — Fundamental diagram of connection for the voltage regulator for individual operation.

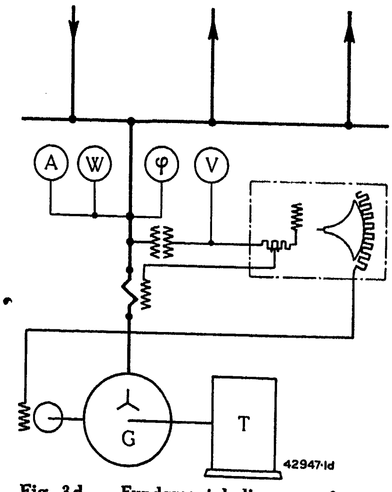

Fig. 3d. — Fundamental diagram of connection for the voltage regulator for parallel operation.

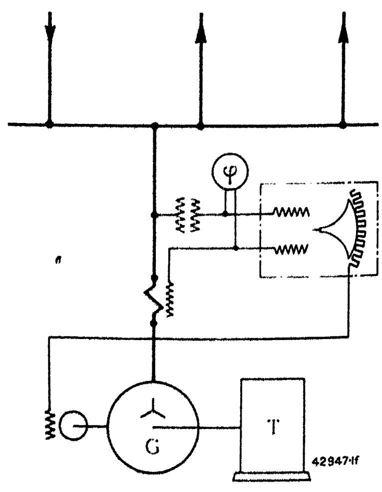

Fig. 3f. — Fundamental diagram of connection for the power-factor regulator or reactive-power regulator.

necessary to combine the effect of the current in two phases, such as R and S, for example, in order to compound the regulators of several alternators having to work in parallel. It is unfortunate that, in many cases, insufficient importance is attached to the question of the proper connection of the current transformer. For this reason the demonstration panel has been fitted with a set of change-over switches allowing of branching the said transformer, as desired, in any one of the three phases and of making the influence positive or negative. This device allows of showing up clearly the favourable or deleterious effect on automatic regulation of a current transformer properly or wrongly connected.

A prejudice which is, still, too widely spread is that it is not feasible to fit a voltage regulator on a small generator working in parallel with a big system, because the small unit cannot regulate its voltage independently of the said system. It is clear that a regulator of astatic characteristic, as is the case for most of the other types of regulator encountered, may over- or under-excite the alternator when fluctuations of the system voltage occur, and this to an inadmissible degree, causing a disturbance in the working of the machine. On the contrary, the Brown Boveri static regulator is the ideal apparatus for the case in point. It only maintains constant voltage if it is possible so to do and dependently on the reactive load of the alternator; thus, the voltage of the alternator adapts itself to that of the system to avoid too big exchanges of current. The operation of the static regulator in parallel operation is followed very easily with the help of this small 6-kVA alternator running in parallel with the town-supply system. As it is impossible to reproduce artificially disturbances on the latter, the balanced voltage of the regulator is modified in order to imitate the real conditions, this being carried out by the adjusting rheostat. This change which is equivalent to a variation in the voltage of the system only causes a slight change in the power factor. When the system voltage is too high, the small generator is slightly under-excited; that is to say its power factor is high because a delivery of reactive power, which would contribute to still further increase the voltage is not necessary at this moment. Inversely, when the voltage is too low, the alternator is over-excited to increase the reactive power delivered and it contributes, in the measure possible, to better the voltage of the system. The static regulator is thus a real automatic field rheostat for alternators of small or of medium outputs.

The voltage regulator of standard type has a torque amounting to 850 gcm and this must be considered as very high if account be taken of the light mobile system of the apparatus. The sensibility of the apparatus attains $\pm 0{\cdot}3$ to $0{\cdot}4\,\%$ and is, thus, sensibly superior to the figure $\pm 0{\cdot}5\,\%$ generally indicated for a good voltage regulator. The consumption of power by the mobile system, which usually plays no part at all, can be brought down to about 50 VA, when special circumstances make it appear advantageous to have a low consumption figure. This reduction does not affect the qualities of the apparatus, as it does when another mobile drum is used. Finally, the symmetrical layout of the two sectors and the utilization of a spiral spring which can be regulated by a single screw eliminate all reactions on the shaft of the regulator.

The sixth apparatus from the left (Fig. 1) is of identical design, it is also a regulator Type AB 2/1 which can be used, with completely loose main spring, as a *power-factor regulator* or, by tightening the said spring, more or less, as a *reactive-power regulator*, the value of the reactive power set to depending on the tension of the spring. These two regulators, however, are only used in special cases. It is, as a matter of fact, advantageous to use a compensated static regulator in the place of a power-factor regulator.

The first apparatus from the left is the *automatic synchronizer Type PB 2/1*. It causes rapid paralleling

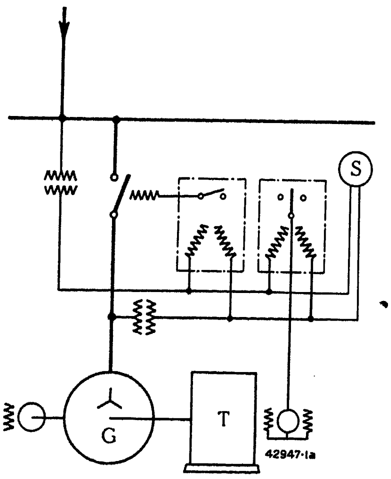

Fig. 3a. — Fundamental diagram of connection of the frequency matcher and automatic synchronizer.

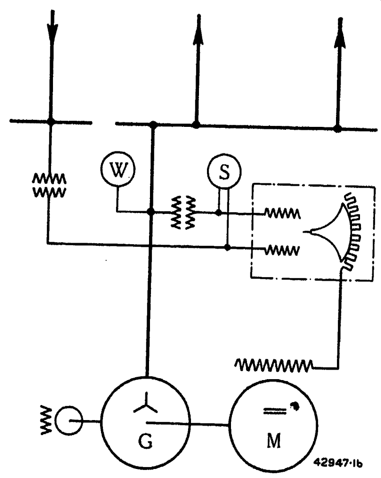

Fig. 3b. — Fundamental diagram of connection of the draw regulator.

of the synchronous alternator with the supply system, without shocks. This apparatus has remained, in principle, identical to the first one delivered, in 1917, to the Aarau Electric Power Station. It has, of course, been perfected thanks to experience acquired with the 500 similar apparatus put into service since that date. By acting on the rheostat of the D. C. motor (or on the brush displacement of the motor) the way the apparatus works is very clearly demonstrated.

Paralleling may be made entirely automatic by making the *frequency matcher Type S 2* work. This regulator, composed of a synchronoscope connected, on the one side, to the system, and, on the other, to the machine to be regulated and acting on two contacts, influences the field rheostat or the brush displacing device, in function of the difference of the two frequencies. It sends out the more impulses the greater the deviation of the frequencies. Near synchronism, the regulating motor gets only very infrequent impulses, which produces very rapid paralleling indeed. Paralleling is, really, so rapid that an additional resistance had to be provided to allow of artificially retarding it in order that the installation should retain its quality of a demonstration equipment.

The next apparatus is a *draw regulator Type H 2* used in the sectional drive of paper-making machines to maintain the speed ratio constant between the different driving motors and, therewith, the tension in the paper between adjacent sections of the machine. As in the case of the frequency matcher, the motor system is composed of a synchronoscope fed, on one side, by a master frequency and, on the other, by a frequency proportional to the speed of the motor to be regulated. Instead of acting on two contacts, the motor system displaces the rolling sectors inserted on the excitation circuit of the motor to be regulated. To show the working of the draw regulator, a comparison is made between the frequency of the synchronous alternator and that of the town system. Despite the variations in the load of the alternator, the ratio of the two frequencies remains rigidly constant, as is proved by the synchronoscope.

Between the voltage and the power-factor regulators is mounted the latest addition to the regulator family, namely *the frequency regulator* (Fig. 3 e). Based on the same principle, its motor system is fed through a self-induction coil and a condenser. At standard frequency, the torques generated by the two windings are balanced, but if the frequency deviates from the standard value, one of the torques increases and the other decreases which causes the mobile system to move round. By means of the self-induction coil which can be regulated, the frequency to be maintained can be adjusted for different values. The frequency regulator is, practically, independent of voltage fluctuations; its precision can be brought as high as $\pm$ 0·05 %. By altering the load of the alternator it is easy to follow the working of the frequency regulator, which acts on the excitation of the D. C. driving motor.

The last two regulators are *control relays Type PB 2/1*, that is to say *impulse regulators.* These regulators, which have the same motor system as those with rolling contacts, can be used as the latter for the most varied objects, that is as voltage regulators, current regulators, power regulators, frequency regulators, power factor regulators, etc., and this as well for D. C. as for A. C. One of the apparatus shown, the diagram of which is given in Fig. 3 g, is

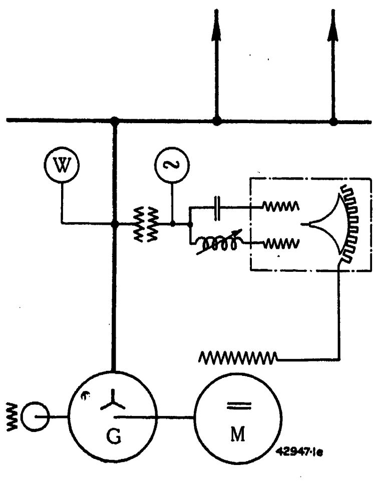

Fig. 3e. — Fundamental diagram of connection of the frequency regulator with rolling sectors.

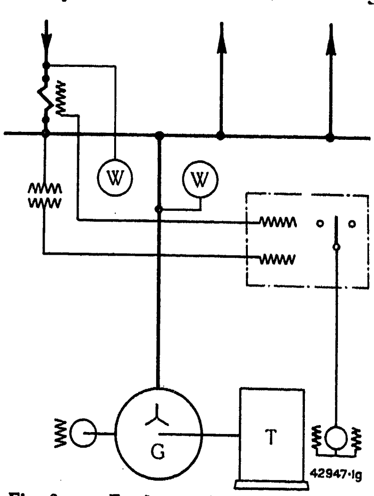

Fig. 3g. — Fundamental diagram of connection of the active-power regulator of the impulse type.

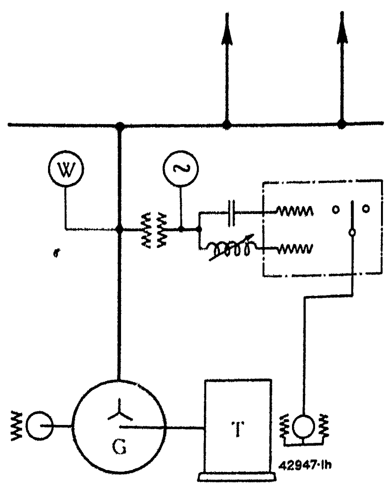

Fig. 3h. — Fundamental diagram of connection of the frequency regulator of the impulse type

a *power regulator* used, for example, in cases where the power taken by a small system or by a shop, having machines which can cover peak requirements, is to be maintained at a constant value. The regulator is connected at the point where the town system comes in and a wattmeter gives the power taken. The load rheostat allows of altering the load, as would happen in a manufacturing shop and the synchronous alternator under the influence of the power regulator acting on the driving motor has to take up all the load peaks. The alternator wattmeter shows the variations in the load of that machine.

The second control relay is a *frequency regulator* which maintains constant frequency by acting not directly on the excitation of the D. C. motor as the rolling-sector regulator (as in Fig. 3 e) did, but indirectly by altering the position of a field rheostat or of the brushes of a commutator motor, through the agency of a little auxiliary motor. This regulator is, also, very sensitive, even more so than the rolling-contact type.

At starting up as an automatic power station, the special apparatus such as the frequency regulator, power-factor regulator, etc., have to be cut out. On account of the large number of switches and change-over switches, it would be easy to make a faulty switching. There is an interlocking circuit which supervises the position of the various change-over switches and a signal lamp lights up when the desired regulators are properly switched in. The plant as an automatic power station then runs in the following way:—

As soon as the starter is actuated, corresponding to the opening of the turbine valve, the set starts up; during the starting period, the voltage regulator regulates the excitation of the synchronous alternator, so that the rated voltage is attained simultaneously with the rated speed. The frequency matcher and automatic synchronizer are, then, supplied from both sides, while the first influences the driving motor of the field rheostat to modify the speed of the set in the sense desired, the latter waits for the first propitious moment to parallel the alternator. Thanks to the frequency matcher, synchronism is rapidly attained, at which moment the automatic synchronizer closes its contact which causes the circuit breaker of the alternator to close. An auxiliary contact on the latter commutates the motor of the speed-changing device in the sense of power increase; during this increase, the voltage regulator regulates the alternator excitation proportionately to the active power delivered. Putting into service is, therefore, identical to what takes place in a hydraulic power station.

There are still a great number of plants, such as small power stations and substations where paralleling is carried out, where the apparatus described here could be used with advantage. Ignorance of the existance of such suitable and cheap devices often leads to the conservation of hand regulation in plants where a few automatic devices would simplify service, increase reliability and improve regulation considerably. On the other hand there is a certain fear attached to the use of automatic apparatus engendered by unfavourable experience gathered when using wrongly designed apparatus, and which reacts against the high-grade apparatus now available. A visit to the demonstration panel with its regulators and relays can be warmly recommended to all those possessing or operating plants of this kind. Generally speaking, the demonstration panel is at the disposal of all parties interested in the question of automatic regulation.

(MS 534) *W. Marolf. (Mo.)*

MOTOR PROTECTION BY THERMAL RELEASES, IN CONTINUOUS AND INTERMITTENT SERVICE.

Decimal index 621. 316. 925. 44.

THE fundamental principle of the thermal release is to supervise the current taken by a motor, or another current-consuming device, by means of an organ, the shape of which changes under the influence of the heat generated by the passage of the current and which trips the switch before the motor or other current-consuming device has attained a dangerous temperature. On account of the mutual influences of heat capacity and heat radiation the thermal release functions, under moderate current variations, with a certain time lag which — to speak generally — corresponds, approximately, to the heat inertia of the lead to be protected; it is, therefore, very suitable to the protective object aimed at. The greater the overload the quicker the release acts and, indeed, should act.

The thermal release has, thus, been assigned the task of following a similar heating-up process to that of the lead it has to protect. However, the heating-up and cooling-off processes in the said lead and release

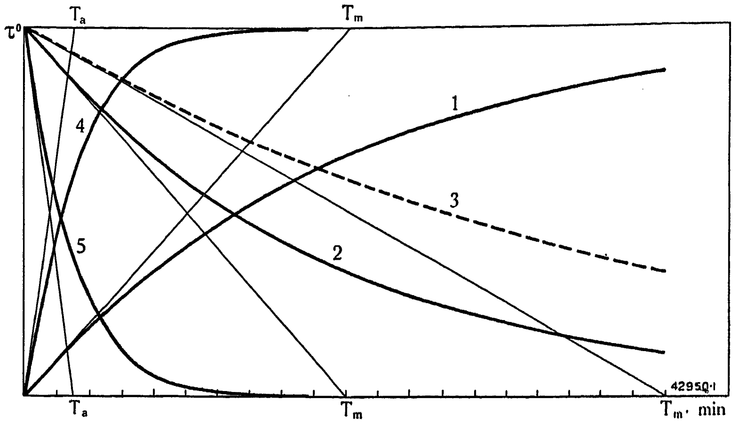

Fig. 1. — Heating and cooling in continuous service.

1. Total heating of a motor in service with the full-rated current.
2. Cooling of a motor still running but with the current supply cut off.
3. Cooling of a motor stopped and with current supply cut off.
4. Heating of a directly-heated thermal release with current supply of rated strength.
5. Cooling of a directly-heated thermal release with current supply cut off.

τ^0. Temperature of equilibrium.
T_m. Time constant of running motor.
T_m'. Time constant of stopped motor.
T_a. Time constant of release.

are not, generally, absolutely the same. In order to understand the phenomena, it is necessary to recall what takes place when a body is heated, which will be summarized, very briefly, with the assistance of Fig. 1.

When the amount of heat imparted to the body per unit of time is constant, the temperature of the said body rises steadily, at first. However, as the difference of temperature between the body and the surrounding air gets greater, the cooling effect grows in intensity. This means that, gradually, a state of equilibrium is approached in which the quantity of heat imparted to the body is equal to that it looses by cooling (curve 1). The heating *time-constant* characterizes a body when it is subjected to heating; by this is meant the length of time required to reach the state of equilibrium just defined, assuming that no cooling of the body takes place in the interval. This constant is represented by the abscissae of the point (T_a, T_m) where the tangent drawn at the origin of the temperature curve intersects the ordinate of the constant temperature.

If the heat input is cut off, the temperature drops, owing to the cooling effect, in a curve which is an exact reproduction of the heating curve (line 2), this on condition that heating and cooling take place under conditions which are absolutely identical, in every respects. If this consideration is applied to electric motors, it must, however, be born in mind that the cooling effect with the motor running is not the same as that when it is stopped. If, for instance, curves 1 and 2 are correct for the motor running (constant speed) with a time constant assumed to be valid for the whole heat of the motor and equal to 20 minutes, the cooling-off, when the motor is stopped, follows a line something like curve 3 with a time constant assumed here to be 40 min.

Lines 4 and 5 shown in the same figure are valid for directly-heated Brown Boveri thermal releases. The character of these curves is the same as that of curves 1 and 2 but the time constants are considerably lower and, only, about 3 min. The fact that the temperature of equilibrium should be chosen considerably higher for the thermal releases than for ordinary motors because of constructive causes, is not of importance for the consideration of the problem.

A motor heats up on account of the losses generated in it, the distribution of which, in the case of an induction motor, are, approximately, that shown in Fig. 2. Some losses—namely mechanical ones (friction and ventilation) and losses in the iron are, practically, independent of the load, while the losses due to the heat generated by the current vary with the square of the current and are, therefore, very dependent on the load. If now the heating of the motor in function of the current is investigated, the current being the magnitude which must be utilized to influence the motor protective device, the following results are reached:

(a) *The total heat caused by losses is no absolute function of the square of the current.* If the total heat generated, when the motor runs with the rated current, be designated by 1, it does not

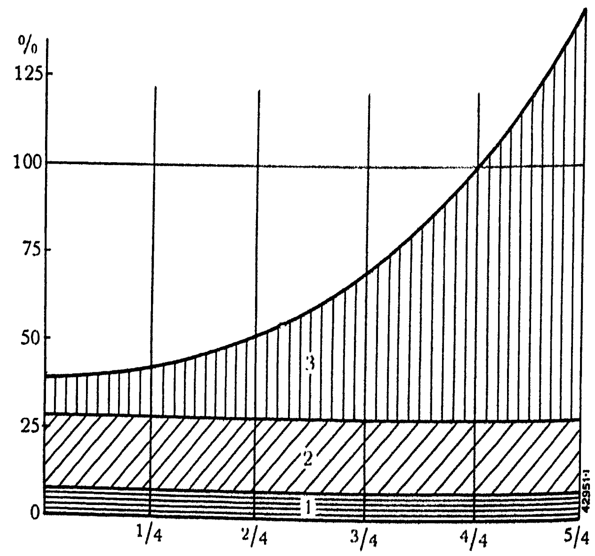

Fig. 2. — Losses of small three-phase motor in function of the load.

1. Mechanical losses. 2. Iron losses. 3. Copper losses.

drop to $^1/_4$ for service with $^1/_2$ the rated current, but is bigger than that figure; while for service with currents greater than 1 it is lower than the value corresponding to the square of the current (Fig. 3). Fig. 4 shows the curves of the total heat due to

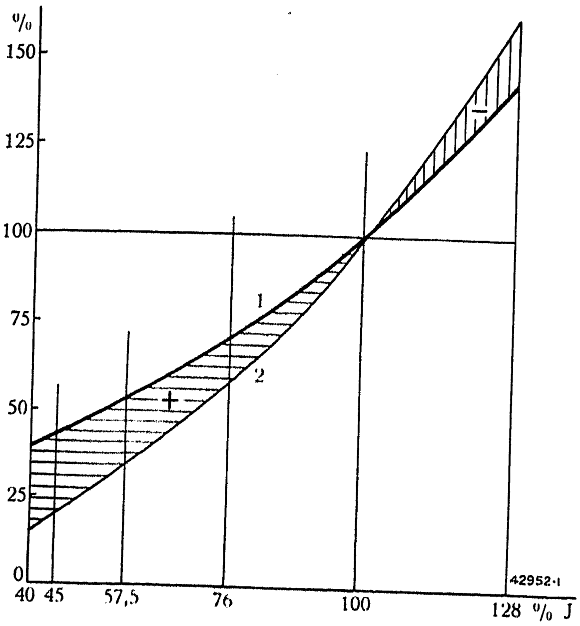

Fig. 3. — **Losses of a motor in function of the current it consumes.**
1. Actual curve of total losses. 2. Curve of J^2.

losses in function of J^2 and according to the percentage participation of the constant losses. The lines are drawn in for 30, 40 and 50 % participation of the constant losses in the making-up of the total losses for 100 % J. The ordinates for any point of these lines give for the current flowing — what the total heat due to losses amounts to as compared to the loss value calculated from J^2, when the latter is assumed to be 1 for J 100 %, that is when it is inserted as being equal to the total losses.

(b) *On account of the exchange of heat between copper and iron the temperatures of these parts*

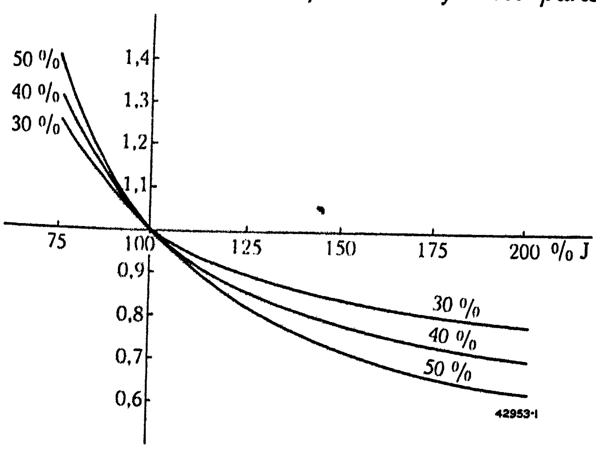

Fig. 4. — Total-losses heating in relation to J^2 in function of current and according to the part played by the constant losses.

do not correspond exactly to the losses of which they are the seat. If the copper losses increase — and, therewith, the heating of the winding, which is the essential factor from the point of view of the motor-protecting device — the heat exchange between copper and iron increases, although with some time lag. When overloads occur, not only the copper but the iron as well gets hotter, despite the fact that the iron losses are no greater.

The heating of the copper in function of the current, will, therefore, be a line lying between that of the total heat losses and that calculated from the function $J^2 R$ for the heat generated by copper losses. For the investigation made, here, it suffices if it is represented, as shown in Fig. 4, namely that the heating of the thermal release under overloads tends towards a higher percentage of excess temperature than that generated in the motor winding to be protected.

This leads to the following conclusion which is important for determining thermal releases:—

The release is in advance, as regards its behaviour, on the motor winding it is protecting, when excess currents flow, as its heating time constant is considerably lower and because the current heat losses in the release are entirely utilized for heating while this is only partly true of the motor winding.

This explains why the protection by thermal release is so reliable and also why there is a possibility, here, of allowing a certain margin, under given conditions, for the setting of the release, as will be shown in the following paragraphs.

Protection of the motor in continuous service.

The curves of Fig. 5 give the clearest illustration of the protection afforded by thermal releases in con-

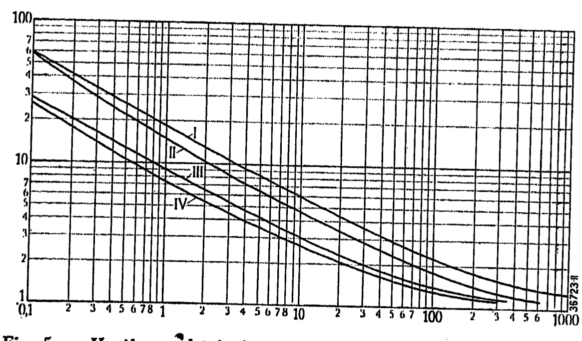

Fig. 5. — Heating and tripping characteristic of the thermal release.

Abscissae. Time in seconds.
Ordinates. Load current as a multiple of the rated current set for (current consumed by motor).
I. Motor danger curve (attainment of highest admissible temperature from the cold state).
II. Tripping from the cold state.
III. Motor danger curve from hot state with continuous service under rated load.
IV. Tripping from hot state at rated load, i. e. following continuous full-load running.

tinuous service. They show, for example, that starting from the temperature attained at full-rated output, the release permits of an overload up to twice the rated current during about 22 seconds. Fig. 6 shows that a motor, of the same heating characteristics as that of Fig. 1 and also taken at the temperature corresponding to full-load service, shows a temperature rise of 3·7 ^{0} C in the time in question. The limitation to this, relatively small increase in temperature takes into account that maximum temperatures laid down for ordinary service conditions must be considered as limit values which it is inadmissible to exceed.

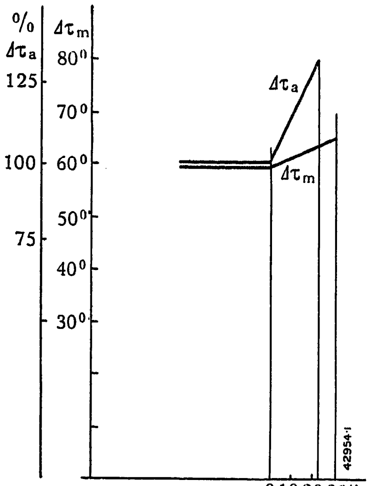

Fig. 6. — Temperature rise in release ($\Delta\tau_a$) and in motor winding ($\Delta\tau_m$) at 100 % excess current in function of time.

The diagram of Fig. 6 shows that the same overload could be allowed for a period of about 30 s before the *"danger line"* is reached. This period, which is 35 % longer, corresponds to a temperature rise of only about 5 ^{0} above the rated temperature rise of the motor. This shows how exactly protection by thermal release follows the requirements laid down by standard rules.

I. PROTECTION OF THE MOTOR FOR REGULAR WORKING CYCLE DUTY.

If the working cycle is that shown in Fig. 7 the r. m. s. value of the current, which is valid for estimating the heating of the motor is given by

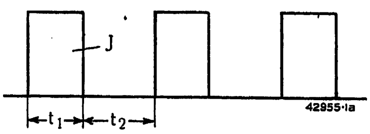

Fig. 7. — Regular working cycle.

$$J_m = \sqrt{\frac{J^2 \times t_1}{t_1 + t_2}}$$

this assuming that the cooling conditions in the periods t_1 and t_2 are equal. This, however, is not the case for motors, as we stated already; further, the current diagram has quite another shape on account of the starting current, especially in the case of squirrel-cage motors (Fig. 8). As the switching-in current value falls back to the rated current value during starting, an average current value must be introduced in order to estimate the current diagram properly and not the switching current surge value. Allowing that the starting accelerations are equal, which is only partly true, the following approximate r. m. s. values of the starting current can be reckoned with.

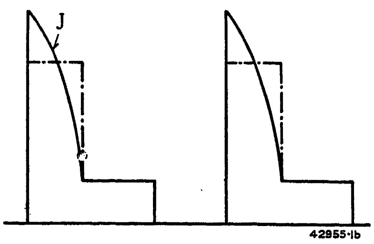

Fig. 8. — Squirrel-cage motor working to regular working cycle.

Switching-in current $I_n \times \ldots$	R. M. S. value of starting current $I_n \times \ldots$
6	4·6
5	3·85
4	3·1
3·5	2·7
3	2·3

What the influence of the working cycle followed should be on the choice of the size of the motor is another question.[1] The present article is limited to investigating how the thermal releases behave under such conditions and how the demands of motor protection are met. This is examined in the two following examples.

(a) *Reversing drive of a washing machine by means of a squirrel-cage motor* (Fig. 9).

Assuming the following conditions:—

Starting period t_a	0·3 seconds
Working period t_b	8·7 »
Stopped period time t_c	3·0 »
Total duration of working cyle $t_a + t_b + t_c$	12·0 »
	(300 working cycles per h)
Current surge at switching in . . =	$4 \times J_n$
Rated current	J_n

The r. m. s. value of the starting current valid for the heating of the thermal release is (according to the table) $3{\cdot}1 \times J_n$ and the average value of the current referred to the total working cycle and setting $J_n = 1$:—

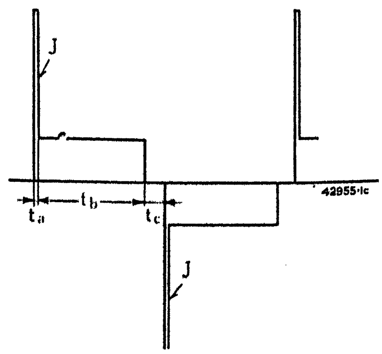

Fig. 9. — Current diagram for reversible drive of a washing machine by squirrel-cage motor.

[1] Compare with The Brown Boveri Review, No. 9, 1929 "Notes on the choice of motors for centrifugals."

$$\sqrt{\frac{0\cdot 3\ s \times 3\cdot 1^2 + 8\cdot 7\ s \times 1^2}{12}} = \text{about } J_n$$

As, according to curve Fig. 5, the starting current does not cause the release to trip the switch in the very short starting period, the thermal release of the motor adjusted to J_n will protect it just as efficiently for a working cycle like this one as in ordinary steady service.

(b) *Centrifugal drive by squirrel-cage* (Fig. 10).

Assuming the following conditions:

Starting period t_a	$= 0\cdot 5$ min
Working period t_b	$= 2\cdot 5$ »
Braking down to standstill t_c . . .	$= 2\cdot 0$ »
Switching-in current	$= 3\cdot 5 \times J_n$
Rated current	$= 0\cdot 5 \times J_n$

The thermal r. m. s. value of the current is again given by:

$$\sqrt{\frac{0\cdot 5 \times 2\cdot 7^2 + 2\cdot 5 \times 0\cdot 5^2}{5}} = 0\cdot 925 \times J_n$$

However, the release cannot be adjusted to this value, because, during the long starting period it would heat up to its tripping temperature. It would be just as great a mistake to determine, from Fig. 5, what excess current the release can carry starting from the full-load temperature and during the whole starting period and, thus, to set the release by so much above the rated current as corresponds to the ratio:—

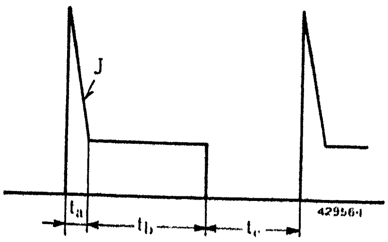

Fig. 10. — Current diagram for drive of a centrifugal by squirrel-cage motor.

$$\frac{\text{Thermal r. m. s. value of starting current.}}{\text{Allowable overload of release during starting period given.}}$$

The date of the example just taken, would lead to the result:—

$$\frac{2\cdot 7}{1\cdot 8} = 1\cdot 5 \times J_n$$

The result would be wrong, because, at the initiation of the starting period, the release is considerably cooled down and the initial heating, therefore, does not begin to act from a temperature corresponding to that of the full-load operation.

Fig. 11 shows how the temperatures behave for the centrifugal drive in question. If the release trips at about 130 % of rated full-load temperature (continuous load corresponding to J_n) service would be impossible because the release would be 147 % hot. In order to prevent the release acting it must be set to, at least

$$\frac{147}{130} \times \text{motor-rated current} = 1\cdot 13\ J_n$$

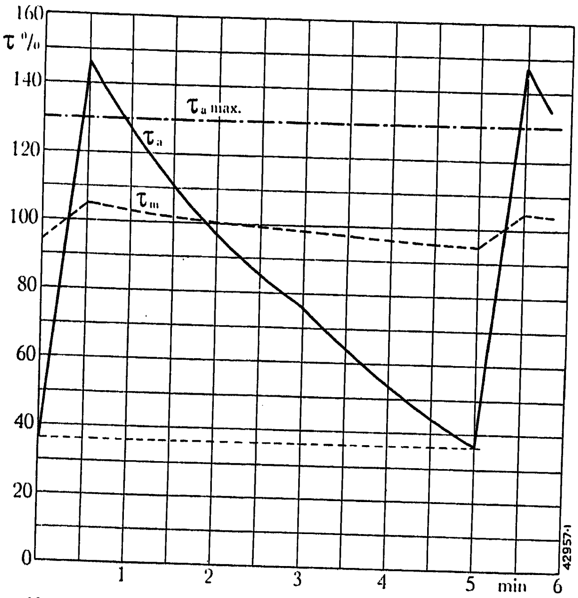

Fig. 11. — Percentage heating of release (τ_a) and motor (τ_m) for drive of a centrifugal.

τ_a max. Temperature at which impactor acts.

In ordinary service, a setting of about $1\cdot 15 - 1\cdot 20 J_n$ would be made.

As compared to the considerable temperature fluctuations of the release the temperature variations of the motor are small as Fig. 11 shows. At the start, the temperature rises by only about 5 %, or by 3° C at 60° C continuous heating, which corresponds approximately to the example given on page 138. There can be no question of the motor being endangered by the relatively big temperature rise at starting.

The question, now, arises as to whether the motor is protected at all by a release to 15—20 % above the motor-rated current. To this can be countered:— what should the motor be protected against? In the case of a motor driving a centrifugal there is no possibility of an overload, as it is ordinarily understood, because an overload of the centrifugal basket does not influence service. Motors to drive centrifugals are dimensioned, primarily, as regards their starting qualities and an overload can only occur if there is some obstruction to starting, namely too long or too violent a starting process. The release protects the motor against this danger, very reliably, being set in view of the starting conditions. *In every case, the particularities of the service must be taken into account when examining the effect of the motor protection.*

II. PROTECTION OF THE MOTOR FOR INTERMITTENT AND IRREGULAR WORKING-CYCLE DUTY.

Service of this kind is generally defined by the number of working cycles per hour of the motor and the relative time it is switched in, or operating time. Thus, for example, by 60 working cycles per hour and 40 % switched-in time, is to be understood service in which the average working cycle last one minute in which time the motor carries its full-load current for 40 % of the time, that is for 24 seconds and is cut out for the remaining time, or 36 seconds.

When chosing motors for such working conditions the starting conditions do not only take the number of starts per hour into consideration but the starting currents and the duration of the starts, as well. For a lift drive, for instance, with 120 switchings per hour, switching-in current $3\cdot 7 \times J_n$ (corresponding to $2\cdot 7 \times J_n$ r. m. s. starting current according to table on page 138), duration of start = 3 s, rated current = J_n with 40 % switching-in time, Fig. 12 will give the heating curve of the motor (line a) and of the release (line b) and this beginning from the service temperature.

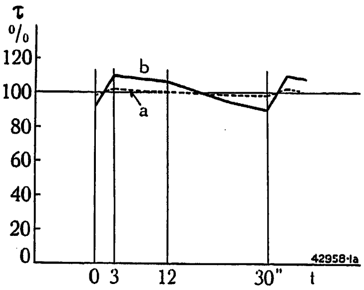

Fig. 12. — Temperature curve in motor (a) and release (b) for one working cycle, for drive of a lift.

As is seen from this, the temperature differences in the motor referred to the total heating are hardly of any importance while those in the release are strongly marked. Nevertheless, the peaks are below the tripping temperature of the release so that the release set according to the thermal average

$$\sqrt{\frac{3 \times 2\cdot 7^2 + 9 \times 1^2}{30}} = \text{about } J_n$$

protects effectively. If starting is much easier than assumed, here, as, for example in 1 second, the release could be set for a much smaller thermal average, namely to

$$\sqrt{\frac{1 \times 2\cdot 7^2 + 11 \times 1^2}{30}} \approx 0\cdot 78\ J_n$$

but this, however, would mean nothing.

Calculations, however painstaking, therefore, fail in practice and can only give some general directives. This is because in lift drive, as in other intermittent services, there is no regular working cycle, but one must reckon with occasional switched-in periods of different durations succeeding each other without a pause between them.

As Fig. 13 shows, this does not damage the motor while the release immediately reaches the tripping temperature and acts, if it is adjusted to the average (thermal) value of the motor. Is it possible to adjust the release for this kind of service and how?

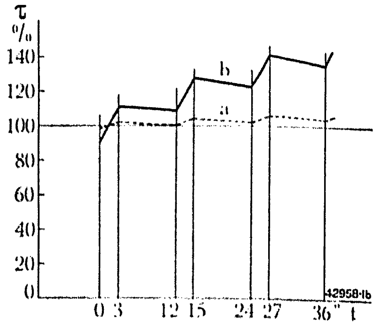

Fig. 13. Temperature curve in motor (a) and release (b) for successive switching-in operation in lift drive.

The most suitable means would seem to be the use of a release the characteristic of which is better suited to that of the motor, that is to say a release with a bigger time constant. As a matter of fact, various manufacturers recommend a special design to meet these cases, with a prolonged time constant. As a rule, however, these releases have a very short time constant in their standard design — one minute for example — so that a lengthening to twice or three times the usual figure only attains the ordinary time constant of the Brown Boveri release. Although it would be possible to increase the thermal capacity of the latter release, as well, this is difficult for economic reasons, quite apart from the fact that it is quite impossible to attain the different thermal conditions of the motor being protected.

Thus, the only solution is to set the release *above* the rated value of the motor current. There is, really, no risk in so doing because, here as well, the thermal average is pushed up by the difficult starting conditions and danger of the motor being overloaded can,

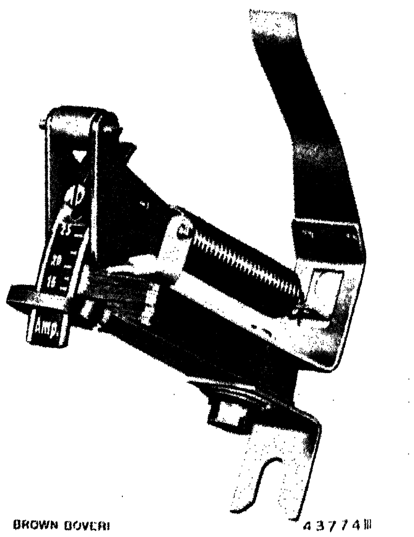

Fig. 14. — Brown Boveri directly-heated thermal release with power-storage device.

really, only arise from too frequent or too long starting periods. For example if, instead of 120 working cycles (of the same duration) there are 150, the (thermal) r. m. s. value of the current goes up by 13 % and by 31 % if there are 200 working cycles. In the case of lift motors, where the working diagram is difficult to determine, a certain margin of safety must be allowed, and these motors are always amply dimensioned. Thus, a passing increase of the average current load of the order of 20 % is out of the question. A release, set to this value, allows that overloading which is absolutely indispensable to lift service but not harmfull to the motor itself and which is due to several working cycles occurring in quick succession; the said release also offers sufficient protection against all overloading possible in this kind of work.

III. CONCLUSIVE REMARKS.

The cases investigated here show the multiplicity of duties demanded of a motor-protection device. They also show, however, that a release the thermal character of which can be thoroughly determined in advance, as is the case for directly-heated releases, can be adjusted to meet difficult service conditions. In this respect, indirectly-heated releases and — even more so — those supplied through a transformer are much inferior. Thanks to its relatively big time constant and mechanical strength of the layers of bi-metal strips, the directly-heated Brown Boveri thermal release fulfils reliably all the practical requirements of efficient motor protection, even in the most difficult cases, such as are encountered in the drive of centrifugals, lifts and elsewhere.

(MS 535) *S. Hopferwieser. (Mo.)*

SOME COMMENTS ON FREQUENCY AND POWER REGULATION.

Decimal index 621.316.726 : 621. 316.728.

THE object of the interconnection of electric power-supply systems is to assure reliable and constant distribution of power to consumers. In itself, however, interconnection gives rise to a number of new problems, one of the most important of which is the regulation of frequency and of output. It is easy to understand that the problem of output regulation is of primary importance, but it is not so easy to see why that of frequency regulation should play an important part. It is, obviously, not with the sole object of distributing power at constant frequency — which is only necessary for certain industries or to supply synchronous electric clocks — that power supply companies undertake the difficult task of maintaining constant frequency. The reason is that maintenance of constant frequency is an absolute necessity if close regulation of power output is to be attained. Frequency and power-output regulation are closely allied, it is impossible to have the one without the other, because, at the first moment of a variation between the power consumed and the power produced, before adjustment through the governors of the prime movers has taken place, the frequency can be considered as a measurement unit of the deviation between the power produced and the power consumed. However, before studying this relationship, it may be advisable to recall how power is distributed in systems which have no particular active-power regulating devices.

I. FREE POWER DISTRIBUTION ON A SYSTEM HAVING NO SPECIAL REGULATING DEVICES.

As is known, power distribution on a system is generally in function of the respective characteristics of the governors of the prime movers. Let us take the case of a system (Fig. 1) in which C is a centre of power consumption, consuming power P which is supplied by two power-producing centres G_1 and G_2. This power production (Fig. 2) is shared between G_1 and G_2, according to the governor characteristics s_1 and s_2 resulting, themselves from the governor characteristics of the different alternators which make up the power-producing capacities of the centres G_1 and G_2. Centre G_1 produces power P_1 and G_2 produces P_2 corresponding to the respective operating points A and B. If, now, the demand for power rises from P to P′, the power produced by G_1 and G_2, respectively, will rise to P_1' and P_2'. The frequency falls from f to f′ which decline will be the smaller the smaller the fluctuation in load, as

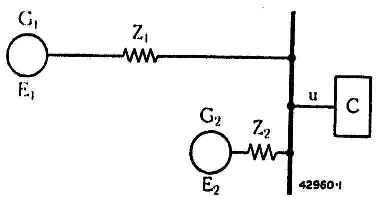

Fig. 1. — Diagram of a type of system.
G_1, G_2. Centres of production.
C. Centre of consumption.
U, E_1, E_2. Voltages at various centres.
Z_1, Z_2. Impedences concentrated between centres of production and of consumption.

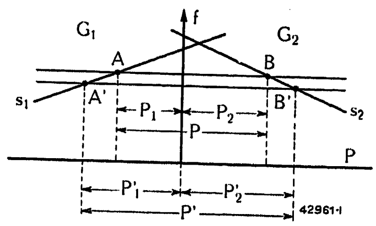

Fig. 2. — Distribution of power in conformity with the governor characteristics of the prime movers.
s_1, s_2. Resultant governor characteristics of centres of production G_1 and G_2 respectively.
P. Power.
F. Frequency.
G. Centre of production.

referred to the total power of the system, and the less inclined the governor characteristic. This last quality, however, cannot be pushed too far as the smaller the inclination of the characteristic the greater the instability of the system.

The passing from output P to output P′, that is to say from the condition of equilibrium A-B to the new one A′-B′ cannot be made, however, without the pole wheels of the alternators undergoing a series of oscillations, the pole wheels having to slip by a certain amount so as to reach a position corresponding to the new output, this being shown diagrammatically in Fig. 3. This is the power diagram — angle of centres of production G_1 and G_2, respectively referred to the centre of consumption. As is known, the respective outputs transmitted from G_1 and G_2, to C can be defined — if the resistance is disregarded — as follows:—

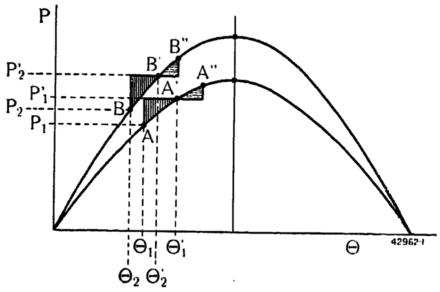

Fig. 3. — Distribution of power in conformity with the electric characteristics of the system.

P. Power.

Θ. Angle of pole-wheel displacement.

$$P_{GC} = \frac{EU}{Z} \sin \Theta$$

Θ being the angle between the vectors representing the voltages E (E_1—E_2) at the centres of production (which can be assimilated to the axis of the pole wheels) and a vector U which is that of the voltage at the centre of consumption taken as reference axis. The power consumed by C being P, the working points will be A and B corresponding to the same points on Fig. 2. The power consumed increasing to P′, the points of stability of the new state thus created will be A′ and B′, but the angles between E_1 and U, on the one hand, and E_2 and U on the other which were Θ_1 and Θ_2 will have to increase to Θ_1' and Θ_2'. In other words, the pole wheels of the machines in the stations G_1 and G_2 will be displaced. However, according to the assumptions made when Fig. 3 was drawn, the pole wheels in centre G_1 should slip further than those of G_2 because the displacement per power unit is greater in the first than in the second. These displacements are, first, initiated by the fact that, at the first moment of load variation, the increase in power is produced by the kinetic energy stored up in the pole wheels which are subjected thereby to a decrease of speed. The governors of the prime movers act on this drop in speed and cause the power delivered by the prime movers to rise from P_1 to P_1' and from P_2 to P_2', respectively, leaving the efficiencies out of account. Thus, under the impulsion of the outputs P_1' and P_2' the rotors will be displaced forward, but in this movement they will store up a certain amount of kinetic energy which can be roughly represented by the vertically-shaded surfaces (Fig. 3). The points of equilibrium A′ and B′ will be exceeded. At points A″ and B″ the relative forward movement of the pole wheels braked from A′ to A″ and from B′ to B″ will be stopped. They will then drop back and the oscillations will continue, being gradually damped down. If the variations of speed, which are small, are disregarded as well as the damping down of the movement and the losses, and if it is assumed that the voltages are constant and that the turbine governor act instantaneously, the movements of the centres of production referred to the fixed axis of reference, in the present case the voltage U, are governed by the equation

$$\frac{I}{p}\frac{d^2\Theta}{dt^2} + \frac{P}{\omega} - \frac{EU}{Z}\sin\Theta = 0.$$

p = number of paires of poles,
I = moment of inertia,
P = motive power,
ω = average angular speed,
z = impedance.

It is obvious that the respective movements of the centres G_1 and G_2 cannot be identical, because the moments of inertia, the voltages and the impedances, which are, here, Z_1 and Z_2, are different. Therefore, there must be oscillations between G_1 and G_2 causing exchanges of power during which the turbine governors may exert undesirable influences. It would, thus, be preferable to reduce the amplitude of these exchanges of power and their number to a minimum, because they may in some extreme, although rare, cases, with very long lines, be the cause of falling out of step of the stations which is contrary to the object pursued when the systems were linked up. Thus to summarize, there are two phases to be considered in the process just described, a first one in which the motor element is the kinetic energy and a second one in which the increase in motor power of the prime mover appears. The first phase cannot be avoided but efforts should be made to influence the second phase, as will be shown further on.

II. FORCED DISTRIBUTION OF POWER ON A SYSTEM.

(a) *Separate regulation of power and frequency.*

The systems which are necessarily made up of various power stations of different outputs and with

working cycles dependent on their own particular characteristics or on power-delivery contracts, must operate to a fixed program of power delivery. By this is meant the obligation for certain power stations to work to constant load or else to a load which varies according to a program or chart drawn up in advance, while other stations are entrusted with the duty of covering the peak loads. Let it be assumed that centre G_1 has to operate to constant output P_1 while G_2 has got to follow the fluctuations in load as they occur, as shown in Fig. 4. If, now, the consumption P rises to P′, the operating points of the respective producing centres will pass from A—B to A_1—B_1 with consecutive drop in frequency, then, under the influence of the governing to constant output of station G_1, to A_2—B_2 this by displacement of the characteristic s_1, parallel to itself as far as s_1', which means a further drop in frequency. In order to reduce this drop in frequency to a minimum as well as the exchanges of power, it might be thought advisable to give the governor characteristic of G_2 a less drooping character than that of G_1, but the inconveniencies of a nearly flat characteristic have already been mentioned. As to giving a very pronounced drop to the characteristic (as just suggested for G_1), this cannot be considered if the centre of production has local conditions to meet, because it may provoke considerable exchanges of power. Thus, one is naturally led to regulate the frequency by G_2 in such a manner that the points of equilibrium for the output P′ will be A and B_3. This regulation is carried out by displacing the governor characteristic from s_2 to s_2'. This regulation of the frequency, the sole advantage of which in the simple case illustrated in Fig. 4, would seem to be an improvement of frequency, is proved to be indispensable, when the problem of several centres of production working in parallel is studied several of which have to produce constant output or an output varying according to a fixed program. Let us assume (Fig. 5) three centres of production G_1, G_2 and G_3 of which the first two have to operate to constant output, P_1 and P_2, respectively, the total output P consumed by the centre of consumption C being equal to $(P_1+P_2+P_3)$. If the power consumed changes from P to P′, the turbine governors will react immediately, as explained before, and the load will be distributed according to the governor characteristics in the sense of increasing the power delivered by each of the centres. The transitory working points will be A_1, B_1, C_1. By definition, the outputs of G_1 and G_2 should remain constant; if the frequency is not regulated at centre G_3, it will be necessary to regulate the outputs at centres G_1 and G_2 so as to attain the points of equilibrium A_2 and B_2. However, the frequency not being determined and the regulating operations — automatic, or even more so, if manual — lagging necessarily as regards time, on account of all the inequalities between the two centres, it is easy to understand that points A_2 and B_2 will only be attained — if attainment is really possible — after long and difficult regulating operations. If, however, instead of regulating the output, the regulation is carried out in centre G_3 to constant frequency everything is considerably simplified. As soon as centre C demands an increase in power, which increase has got to be taken care of by G_3, as said before, the latter station regulates to frequency and causes the system to pass easily from points A_1, B_1, and C_1 to points A, B, and C_3; in other words, the regulation of the frequency has satisfied the requirements of the power regulation.

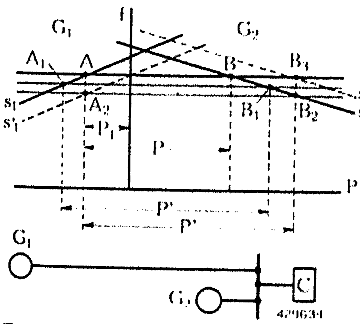

Fig. 4. — **Forced distribution of power.**
G_1, G_2. Centres of production.
C. Centre of consumption.
P. Power.
f. Frequency.
G_2 regulated to constant frequency.

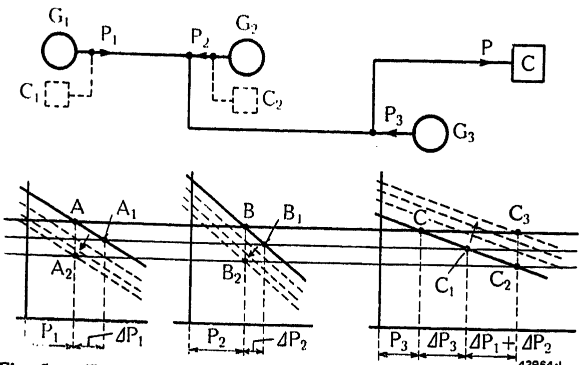

Fig. 5. — **Forced distribution of power with separate regulation of frequency and power.**
G_1, G_2, G_3. Centres of production.
C_1, C_2. Centres of local consumption.
C. Centre of main consumption.
G_1, G_2 regulates to constant power output P_1 and P_2, respectively.
G_3 regulates to constant frequency.

A frequency regulation at centre G_3, alone, is not, however, a possible solution because, practically, each centre of production has got its own centre of consumption, the load of which fluctuates. Therefore, the regulation of frequency must necessarily be accompanied by a certain amount of power regulation on the interconnecting lines of the centres and vice versa. At a first glance, it would seem that we are back again with the same difficulties as encountered for output regulation alone. It is true that these difficulties may reappear in part, but to a lesser

degree because one unknown factor — the frequency — is eliminated. It will be seen, at once, that the quicker the centre regulating to frequency reacts the better regulation will be, and here a remark should be made. In this type of regulation with distributed functions, considerations of efficiency rather than of suitability are the deciding factors in the choice of the power stations called on to regulate to frequency. Thus, in this kind of regulation, low-head hydraulic plants, working with the whole volume of water available, will be eliminated, because it is of great importance to utilize all the water power available. Further the relatively sluggish reaction of the turbines makes this type of station unsuitable for frequency regulation. But this objection is one of principle, only, because by making use of certain available devices, with low-head turbines, the object of which devices is to compensate their sluggishness, quite unhoped for regulating qualities can be attained and perfect maintenance of frequency as well. However, the turbines, of high-head plants possess the desired qualities to a very high degree and they are, generally, called on to regulate the frequency, the question of water consumption not being an important factor here owing to the existence of lake storage facilities for the available surplus. As to thermal power stations, the rapid reaction of the steam turbine would seem to designate them for frequency regulation. Nevertheless, on account of the boilers, it seems generally advisable to let them deliver as constant a load as possible, which is certainly regrettable from the regulating point of view. Frequency regulation imposes very heavy and, often, very rapid fluctuations in load, which are not desirable with ordinary boilers. These difficulties are surmounted thanks to the new quick-reaction boilers, of which the Brown Boveri Velox steam generator is the most characteristic type.

As regards the power of the frequency regulating station, it must, obviously, be as powerful as the maximum load-variation peak. It may happen, however, that this condition is not fulfilled. In cases like this, the regulating system fails and another regulating system should be made use of, which is described in the following paragraphs.

(b) *Separate regulation of the frequency and of the output, with limitation by the frequency.*

In the system just considered, the regulation of power delivered is independent of the frequency. Now, owing to an unexpected demand for power, or because one of the main supply stations has to shut down or, yet again, because one of the generating units in the station regulating the frequency is cut out, it may happen that the power of the said station does not suffice to meet the demand for power and it gets overloaded. Therefore, to meet such an emergency, it is essential to back up the power regulation by a supervision by means of the frequency, so that the latter takes the place of the power as a regulating magnitude as soon as a certain range of frequency variation is exceeded. For regulating purposes proper, this limitation dictated by the frequency has the advantage of attaining, in quicker time, states of stability, because it reduces exchanges of power. If Fig. 5 is studied, it will be seen that in the initial period just following a variation in power consumed, the centres delivering the said power (G_1 and G_2) act, under the influence of their power governors, in the sense of the arrows, in counter-sense to those stations regulating the frequency (G_3) a state of things which, obviously, leads to heavy exchanges of power. By holding up or, rather, suspending the regulation of power output as soon as the frequency varies too much in one sense or the other and by replacing it by a regulation of frequency, all the centres will regulate, during a certain time, in the same sense which increases the rigidity of the whole system. There can be no question that with this second regulating system advantages are attained, but it is impossible to sufficiently reduce the oscillations produced from all load fluctuations, this applying to the load fluctuations of the centre of consumption and of the various other centres, on which the governors act invariably.

(c) *Combined regulation of frequency and of output.*

It is not logical that some variation taking place on a purely secondary branch system should be the cause of all the electric regulators of the system initiating a regulating operation which results in undesirable displacements of the load. This led to the attempt to reach a combined regulation of the frequency and of the output of such a nature that each centre of production regulates the frequency and controls the output. Let us consider (Fig. 6) two centres of production G_1 and G_2 with their own particular — or local — power consuming centres C_1 and C_2 but which are also called on to deliver, by power contract, blocks of power P_1 and P_2, respectively, to the chief centre of consumption C. The load peaks of the latter are covered by G_3. Regulation will take place in such a manner that each centre G_1 and G_2 must cover local needs, only, besides delivering the power contracted for. This regulation, which must be automatic, is at constant frequency under a combined action of the frequency regulators and of the power regulators and this takes place in the following manner:—

The initial state chosen is one of stable operation characterized by points A, B, and C for which P_1 and P_2 represent the blocks of power contracted for and P_1' and P_2', the additional amounts of power

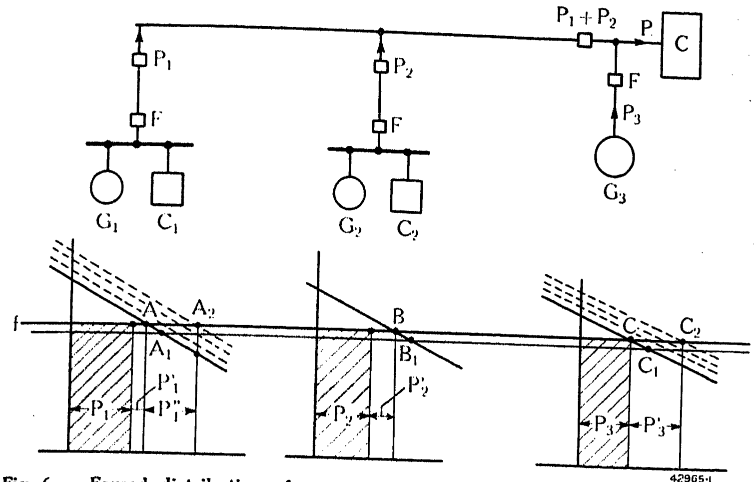

Fig. 6. — Forced distribution of power with combined regulation of frequency and power.

G_1, G_2, G_3. Centres of production.
C_1, C_2. Centres of load consumption.
C. Principal centre of consumption.
P. Power regulator.
F. Frequency regulator.

G_1, G_2 regulates to contracted power delivery and to constant frequency.
G_3 regulates to constant frequency according to C.

consumed by the centres C_1 and C_2, while P is the total power consumed by centre C and equal to $P_1 + P_2 + P_3$. If, now, the local consumption P_1' taken by C_1 increases to P_1'' it will be shared up, at the first moment, and before a stable condition is reached, as already explained, among the different centres and, for a moment, the working points will be A_1, B_1, and C_1. In other words, the increase in power consumed has produced a drop in frequency and falsifies the loads contracted for, because P_1 will have gone down while P_2 and P_3 will have gone up. But this change in regime really concerns the G_1 C_1 system alone, and this is the only system which should have reacted to the increase in load, the others should not have been affected. The desired result is attained by allowing the regulation of G_1 to act freely and by blocking the regulations of G_2 and G_3 and this as follows:—

In centre G_1 the regulators show:— frequency low, contracted power (P_1) low, the regulating system is free to act. In the centres G_2 and G_3, on the contrary, the regulators indicate:— frequency low, contracted power (P_2) high and ($P_1 + P_2$) low, the regulating system is blocked. The points of stability will be A_2, B and C. In the same way, if there is a drop in the local power consumption of C_1, the frequency would rise. The regulators of G_1 would indicate frequency high and contracted power high while one would be high and the other low for G_2, and both would be high for G_3, the regulating systems would be blocked. If, now, an increase of the power P_3' of the chief centre is considered and if, in order not to complicate the figure, it is assumed that P_3' is equal to P_1'', at the first moment there is a transition from operating points A, B, C to A_1, B_1, C_1. Centres G_1 and G_2 which will show low frequency and high output will have their regulating systems blocked while the regulators of G_3 showing frequency low and output high will give free regulation, so that the new state of stability will be A, B, C_2. It is to be understood that the blocking operations only take place within a certain zone of frequency, for the same reasons as explained previously. Each power governor will, thus, be supervised by the frequency in such a way that the various centres of production are able to render each other support if one of them fails. This combined system of frequency regulation and of power regulation while eliminating, by interlocks, sudden regulating surges, also limits the results of ordinary fluctuations of load on the system affected. The exchanges of power between the different systems are reduced to the minimum possible with the regulators available to-day. Does this mean that this minimum could not possibly be further reduced? Certainly not, but this leads to a closer investigation of the part played by the governors of the prime movers.

(MS 533) *(To be continued.)* *F. Werthmann. (Mo.)*

NOTES.

The Beckenried-Klewenalp aerial ropeway (Switzerland).

Decimal index 625.433 (494).

A short report was made in the July number, 1936, of The Brown Boveri Review (page 194) on the first development stage of the Beckenried-Klewenalp aerial ropeway, on the lake of Lucerne and on the subsequent transformation of this ropeway for a higher carrying capacity and to meet the requirements of Swiss Government Traffic Regulations. The following paragraphs give some more detailed information on the technical characteristics of this line. Messrs. R. Aebi & Cie., A.-G., of Zurich, were general contractors for the making-over of the said ropeway and this firm gave Brown Boveri the order for the electrical equipment; the von Roll Ironworks and Foundry in Berne being entrusted with the delivery of the driving gear and running gear of the new cars. The line runs in shuttle service with two cars which travel over a cable length of 3110 m with a difference of altitude of 1143 m; the travelling speed being 4 m/s and the trip requiring about 13¹/₄ minutes.

The driving gear is in the bottom station, where the cable-tightening device (by suspended weight) utilized for the four carrying cables, is also located. These carrying cables are of 34 and 37 mm diameter, two cables

distanced by 280 mm form the line on which the car runs. The said cables are securely anchored in the top station. Each car is moved by two traction cables of 17 mm diameter, led over two double-grooved cable pulleys and one reversing pulley and which are tightened in the top station. The cable pulleys are driven by the main driving motor through a bevel gear and a common differential gear. There is an auxiliary motor working through a belt drive and, also, a hand-driven crank chain-wheel drive which, both, work on the same driving shaft, these auxiliaries being used as electrical or manual emergency drives in case the main drive should be damaged or current be cut off on the supply system, for a long period.

The mechanical braking devices comprise two free-fall brakes which both act on the main-motor shaft through the agency of brake shoes applied to two brake discs and a band brake for hand operation working on a brake disc combined with the cable pulley. One of the free-fall brakes is electrically controlled by means of the new electro-hydraulic thrustor which was introduced by Brown Boveri to replace big brake-lifting electro-magnets and motor-driven brake releases. This thrustor has an adjustable free-fall damping characteristic which results in the cars being braked down, without shocks, when the brake is applied and whatever the travelling speed may be. It is, usually, only employed for the final stopping of the cars at entering the stations and is operated by the controller. It acts automatically, however, in the following eventualities:— if current fails, if the highest travelling speed allowable is exceeded by about 10 %, if the cars run passed their normal stopping point in the stations, if the pendular movement of the traction cable tightening weights in the top station is too pronounced and if the brakes on the frame of the cars proper are applied. It can also be applied from the cars themselves, by push-button control. At the same time, the winding gear motor is cut out, automatically. The second free-fall brake acts as a safety brake and intervenes automatically when a centrifugal governor on the main driving shaft acts, which happens when the speed of the drive reaches about 15 % overspeed and when a mechanical contact on the car is actuated when the latter comes up against the sprung buffers in the bottom station. This brake can also be applied by hand from the operator's stand. The hand brake is only used to regulate the travelling speed when the cars are being run by the emergency driving gears. Finally, mention may be made of the grip-brake device in the frame of the cars which grips the carrying cables

Fig. 1. — Beckenried-Klewenalp ropeway with view on lake Lucerne and the Rigi.

instantaneously if the traction cables break and, thus, prevent the car running away. In an emergency this brake can also be released by the conductor in the car.

The most important part of the electric equipment, apart from the main driving motor, 60-kW continuous rating at 950 r. p. m., 440 V terminal voltage, is the converter set for the supply of the ropeway, designed on the Ward-Leonard system. It comprises a three-phase induction motor of 70-kW rated output at 1460 r. p. m., 380 V terminal voltage, 50 cycles, a D. C. generator of 75-kW rated output at 460-V terminal voltage and an exciter of 2·4-kW rated output at 115-V terminal voltage. There is, also, the three-phase auxiliary motor of 37-kW rated output at 950 r. p. m. which was taken over from the earlier driving equipment.

The regulating of the travelling speed of the railway is carried out by altering the excitation of the generator which effects a corresponding change in its voltage and, thus, the speed of the constantly excited winding-gear motor. To this end, there is a reversing controller with 20 steps for each sense of rotation of the motor. There is a determined travelling speed for each step which remains, practically, constant for every load, either when the cars are travelling under power or under braking. The connections of the total electrical devices for service with the main drive is such that, for travelling under power, the controller mentioned is, alone, required. It allows of starting, regulating the travelling speed on the trip and of stopping in the end stations by electrical braking down to a low speed for entering the said stations and the final stopping with the aid of the electrically-controlled free-fall brake, and this in the simplest manner. In the case of service with the auxiliary drive, the hand-operated brake is required, besides a second corresponding controller, for entering the stations.

Obviously, there are electric safety devices to safeguard the railway, apart from the mechanical ones. The two three-phase machines are connected up to the electric supply through switchboxes with thermal overload protection and no-voltage relays. If the main motor has been overloaded for a long time, a thermal over-current relay causes service on the line to be stopped. There are end-travel switches and auxiliary contacts on the car-position indicator which supervise the trip of the car. There are centrifugal switches on the motor and on the converter set which serve as protection against the highest allowable speed being exceeded. Electric interlocks between the main and auxiliary drive, as well as between the various apparatus, prevent faulty switching operations. An emergency push-button allows the cars to be stopped immediately without the controller having to be brought back first.

All apparatus as well as the measuring instruments and car-position indicator are concentrated on one switch-gear desk, this apart from the devices which have to be directly connected to specific parts of the plant. The excellent surveillance of the control devices which this arrangement permits increase the safety of the line and make supervision of the plant very much simpler.

The new equipment was put into service in the Spring of 1936. Up till to-day, all the equipment has shown itself very suitable to the working conditions of the line.

(MS 543) *E. Hugentobler. (Mo.)*

The Brown Boveri hot-water electric boiler for central-heating installations in the plants of the Cercle Ouvrier, Lausanne, and the Bâtiment du Pont de la Machine, Geneva.

Decimal index 621. 181. 646 : 697. 3.

THE two installations in question are equipped with hot-water electric boilers built for the same conditions of output and operation, namely 250 kW maximum continuous power input, corresponding to 210,000 kcal/h at 380 V and 50 cycles.

The only difference between the two plants is in the height of the water column of the heating system and in the temperatures of the initial flow and of the return flow of water. However, these factors have no great influence on the output or on the dimensions of the boiler.

Fig. 1 is a section of the Brown Boveri hot-water electric boiler, and Fig. 2 gives the fundamental diagram of the complete plant with the electric connections of the boiler and auxiliary drives.

The electrodes, suspended to the cover by means of bushing insulators, are immersed in the water. The electric current flows from the electrodes through the boiler water and heats up the latter. If the boiler is supplied with a large amount of water, it will take more power, while a low level of water in the boiler corresponds to a low power input. It is possible to regulate the load, gradually, from 0 to 100% of the full rating.

The Brown Boveri hot-water electric boiler operates in the following way:—

The water in the boiler is heated up to the saturation temperature corresponding to the height of the water column measured up to the expansion tank. In this way and according to the water column, the following temperatures are attained:—

Height	5	10	15	20	25	30 m
Temperature	111	120	127	133	138	143° C

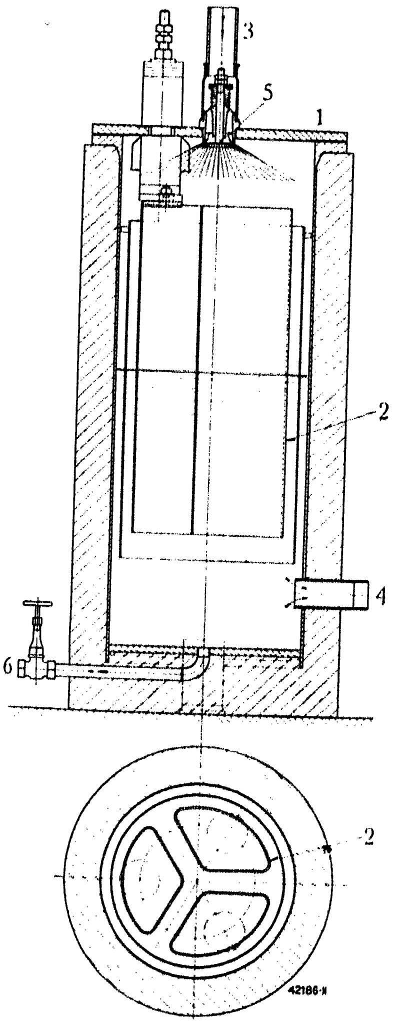

Fig. 1. — Brown Boveri hot-water low-voltage boiler.

1. Electric boiler.
2. Electrodes.
3. Hot-water inlet.
4. Hot water outlet.
5. Distributor.
6. Drainage.

Steam forms in the upper part of the boiler, which is condensed by the water introduced through the injection nozzle. If the heating requirements drop, the temperature of the water injected goes up first. The pressure exerted by the cushion of steam rises and a part of the water in the boiler is expelled to the expansion tank 6 through the auxiliary tank 5. This causes the level of water in the boiler to drop and the power input drops, as well, until equilibrium is again established between the power input and the power delivered. If, on the contrary, more heat is drawn from the boiler than corresponds to the electric power input, all the steam gets condensed. This causes the pressure to drop, and water flows in again from the expansion tank 6 until the power input has gone up so far that it corresponds to the increased heat delivery.

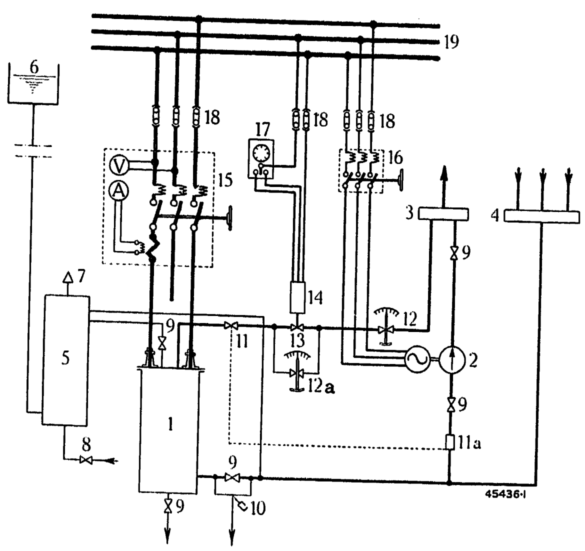

Fig. 2. — Fundamental diagram of a hot-water electric boiler plant.

1. Electric boiler.
2. Circulation pump.
3. Hot-water distributor.
4. Hot-water collector.
5. Compensating tank.
6. Expansion tank.
7. Deaerating valve.
8. Additional water.
9. Valve.
10. Safety valve.
11. Governing valve with thermostat control.
11a. Thermostat.
12. Power input limiting valve.
13. Motor-controlled valve.
14. Motor control.
15. Switchbox for electric boiler.
16. Switchbox for motor of circulation pump.
17. Clockwork switch.
18. Fuses.

As the water available in the boiler is too hot to be used directly in the central heating system, it must be mixed with the return-flow water from the central heating system, and in such a way that the resultant

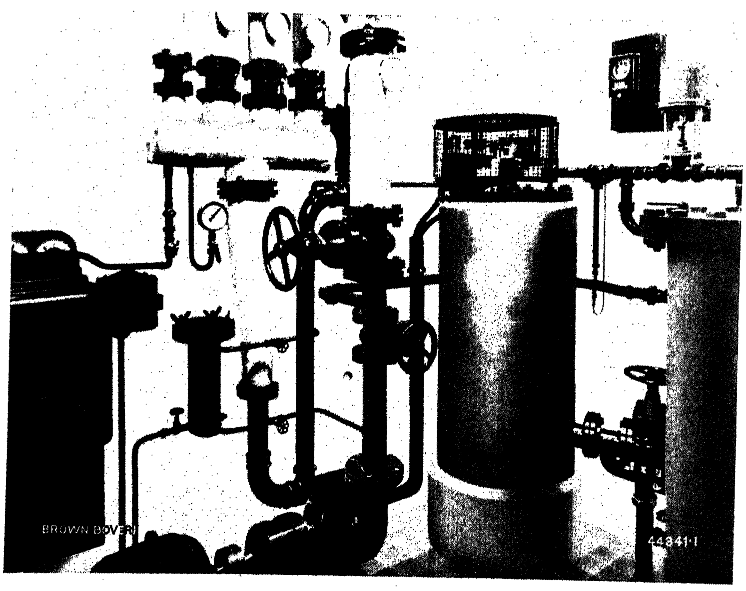

Fig. 3. — Cercle Ouvrier, Lausanne. Hot-water electric boiler, 250 kW, 380 V.

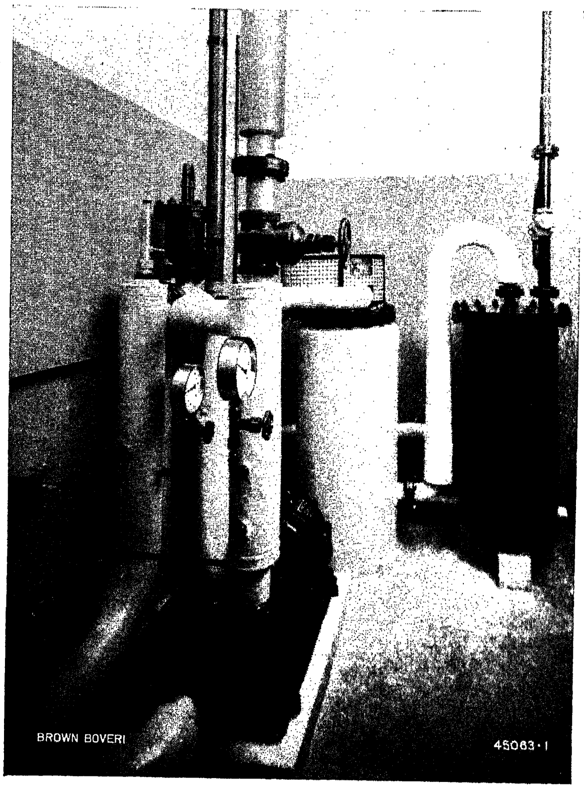

Fig. 4. — Installation Pont de la Machine (Geneva). Hot-water electric boiler 250 kW, 380 V.

mixture attains the temperature desired for the initial flow. Just after the pump, a part of the water of the initial flow is led back to the boiler through governing valves 12 and 11, where it is brought up to boiling temperature. Thus, with constant initial flow temperature, the power input to the boiler is directly proportional to the amount of water supplied. The input is 4·18 kW for one litre of water per second and for each °C of temperature rise. Thus the input is regulated by the amount of water supplied to the boiler.

A determined temperature, fixed in advance, for the initial flow, is held to, automatically, by the thermostats 11a in connection with the governing valve 11. Valve 12 can be so adjusted by hand that a certain maximum amount of water cannot be exceeded. This valve thus operates as a power-input limiter. The second valve 12a and the motor-controlled valve 13 serve to limit a determined maximum input during certain periods, this in combination with the switch clockwork 17; the input in question is set by means of valve 12a. During the controlled period, valve 13 is closed and valve 12a only lets so much water through as corresponds to the limited input adjusted for. After this controlled period is over, valve 13 is opened again, so that the duty of limiting the load is taken over by valve 12. For inputs lower than the limit value set to, thermostat-valve 11 does the regulating. Thermostat 11a could be replaced by an air thermostat, placed in a room, so that the power input to the boiler would be regulated to constant room temperature.

Fig. 3 shows the electric boiler plant in Lausanne, and Fig. 4 that in Geneva.

To conclude, attention should be drawn to the simple layout of both plants and to the entirely automatic service using very simple governing gear, working most reliably.

As regards the electrical switchgear, the Lausanne plant has a switchbox with overcurrent relays on the 380-V side. The Geneva plant is connected straight to the low-voltage terminals of a transformer, and the switchgear is inserted on the high-voltage side of this transformer.

Finally, it should be noted that the Brown Boveri hot-water electric boiler operates with water at the saturation temperature, which does not prevent using it in conjunction with an accumulator, the dimensions of the latter being much smaller than those of ordinary accumulators, on account of the high temperature of the water. We would refer here to our publication No. 1445 E on this subject, which gives a more detailed description of the Brown Boveri hot-water boiler used in conjunction with steam accumulators.

(MS 546) *E. Soldati. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009. 2) : 621. 313. 322.

THE Italian firm Cotonificio Verbanese in Intra took over from Messrs. Sutermeister & Co., its predecessor, a number of electric generators and motors, delivered by Brown Boveri between the years 1894 and 1902. This material comprises a horizontal-shaft 20-pole single-phase generator of 32 A, 3000 V, 42 cycles, 250 r. p. m. rewound in October of the year 1902 for three-phase delivery. Since that period, it has operated as a three-phase generator, 167 kVA, 3000 V, 40 cycles, at the original speed. A further horizontal-shaft three-phase generator 125 kVA, 3000 V, 250 r. p. m., of similar design was delivered in the year 1902. Further, in 1899, Brown Boveri delivered a vertical-shaft generator for three-phase current and 260 kVA, 3000 V, 417 r. p. m.

Brown Boveri delivered a whole series of single-phase motors at that period, which were later rewound for three-phase current and which had outputs varying between 20 and 60 kW. One of these units carries the exceptionally-low workshop number 394!

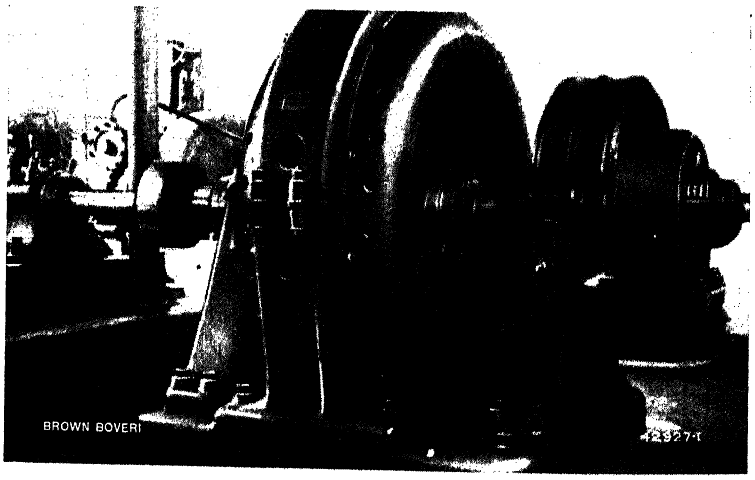

Fig. 1. — Cotonificio Verbanese, Intra. Brown Boveri generators delivered between the years 1894 and 1902.

All these machines are running perfectly, to-day.

(MS 948) *Prop.*

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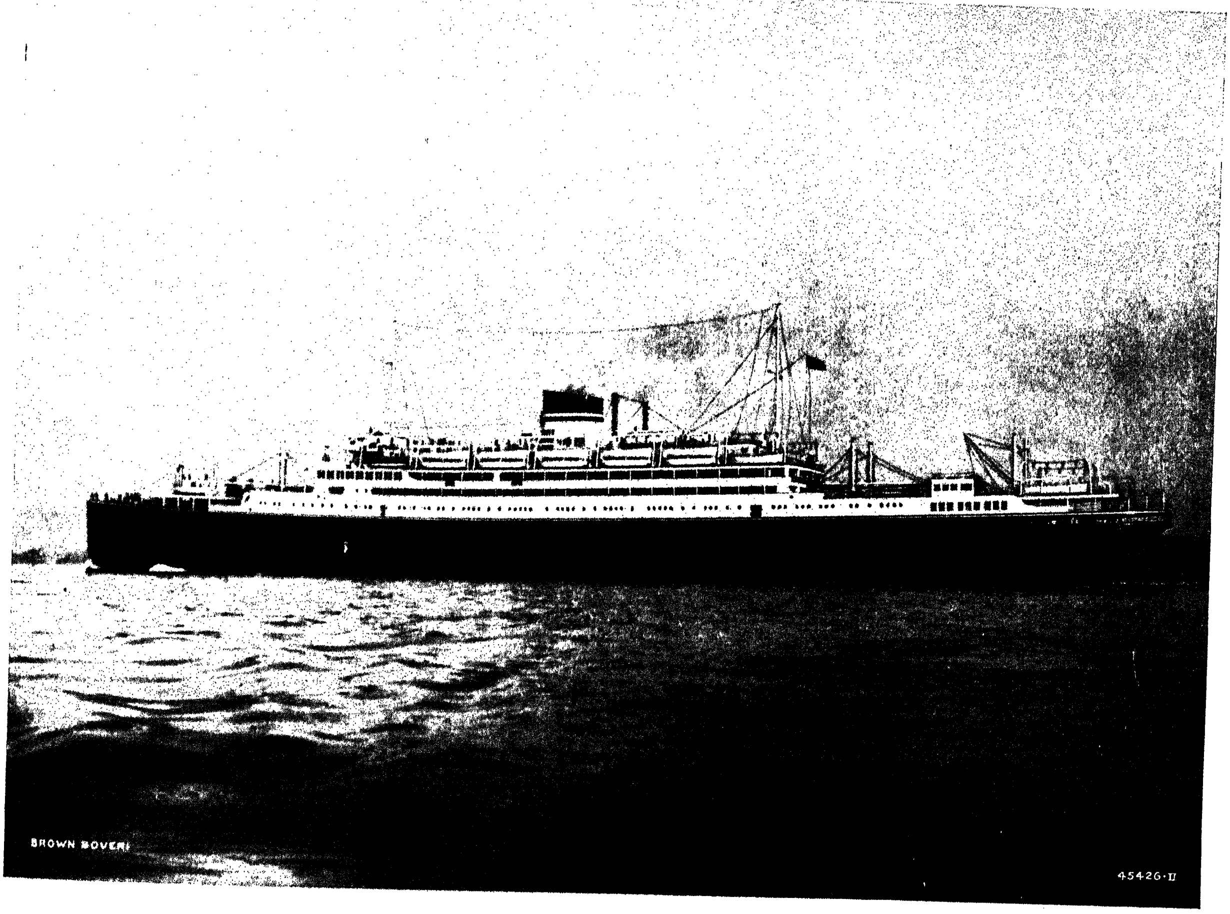

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equipped with two double-acting two-stroke engines of C. R. A.-Sulzer design, delivering a total of 40,000 S. H. P. and three Brown Boveri scavenging turbo-blowers, delivering a total of 5400 m³/min.

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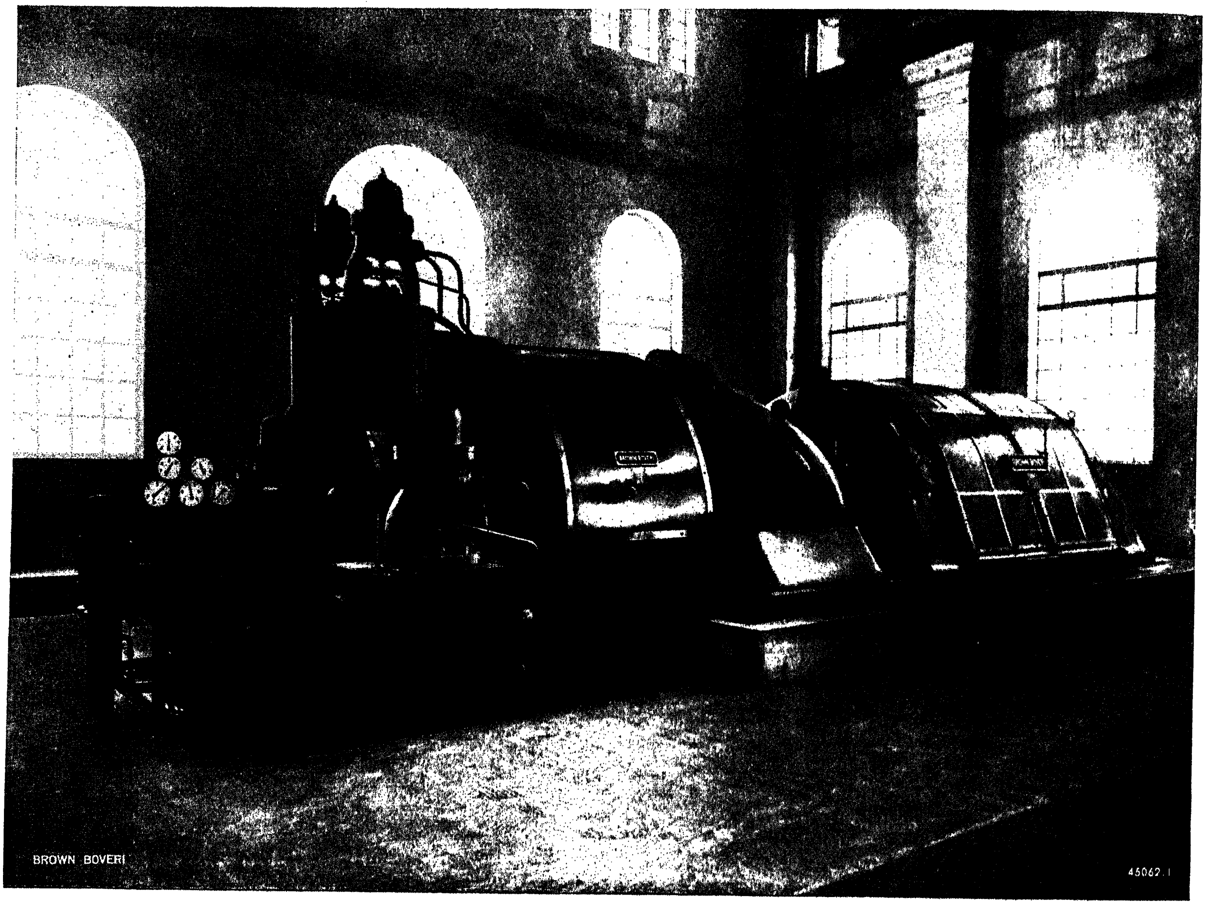


Bucharest Electricity Works (Roumania).
Turbo-set of 20,000 kW, 3000 r. p. m., 20 kg/cm² abs, 380° C, 24,000 kVA, 5600 V, 50 cycles.

Condensing-, back-pressure, extraction and mixed-pressure turbines for all practical conditions

Steam turbines for the highest steam pressures and temperatures, as well as for the biggest outputs per unit

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIV JUNE, 1937 No. 6

AN AMERICAN DIESEL LOCOMOTIVE WITH THE BROWN BOVERI SERVO FIELD-REGULATOR CONTROL.

Decimal index 621.335.2.033.44 (73).

DURING the second half of the year 1935, a new Diesel-electric shunting locomotive was demonstrated before the chief railway companies of the United States. Thanks to its remarkable operating qualities, it aroused great interest among railway men. This locomotive was built by the well-known Baldwin Locomotive Works in Philadelphia, one of the biggest and leading concerns in locomotive construction in the United States. The 660-H.P. Diesel engine was delivered by the De La Vergne Engine Company, Philadelphia, a firm belonging to the Baldwin concern, the electric equipment being built by Brown Boveri's licencees in the United States, the Allis Chalmers Manufacturing Co., Milwaukee. The system of electric transmission chosen is that already described in the December number of The Brown Boveri Review, 1935 and termed the Brown Boveri servo field-regulator control, this being the first time it has been introduced to Diesel-electric locomotive control in America.

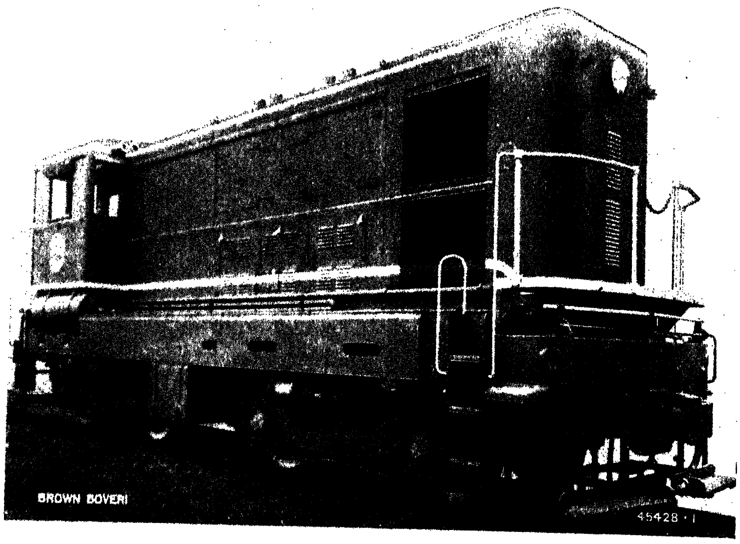


Fig. 1. Bo-Bo Diesel-electric shunting locomotive, 660 H.P. built by the Baldwin Locomotive Works.

Fig. 1 shows the *general design* of the locomotive. Taking into account that the machine is called on to run on shunting lines and on the branch lines of plants, with curves of only 35 m radius, a design with two two-axle bogies was chosen. As this is a shunting locomotive, there is only one driver's cab provided, which conforms to American and also to recent European practice, the cab being located, in the present case, at the rear end of the locomotive, further, there is only one driver's post located on the right-hand side. In order that the operatives may have an uninterrupted view forward, as well, the part of the locomotive housing covering the machinery plant is made as small as is feasible. The main characteristics of the locomotive will be found in the following table:—

Gauge	1,435 mm	(4′ 8½″)
Total length over couplings	12,039 mm	(39′ 6″)
Span between bogie pivots	5,486 mm	(18′ 0″)
Rigid wheel base of bogie	2,438 mm	(8′ 0″)
Width overall	3,099 mm	(10′ 2″)
Height to top of cab	4,343 mm	(14′ 3″)
Diameter of driving wheel	1,016 mm	(3′ 4″)
Tare (weight on drivers, light)	about 91 t	(200,000 lbs)
Maximum weight, ready for service (weight on drivers loaded)	about 97 t	(212,000 lbs)
Maximum tractive effort	about 29 t	(63,600 lbs)
Tractive effort, one-hour rating	18500 kg	(40,700 lbs)
	at about 5·9 km/h	(3·7 m.p.h.)
Maximum travelling speed	72 km/h	(45 m.p.h.)

Capacity:	Fuel	about 1900 l	(500 gal)
	Lubricating oil	about 490 l	(130 gal)
	Water . . .	about 940 l	(248 gal)
	Sand	about 1000 kg	(2200 lbs)

The tractive efforts at the wheel tread and the corresponding travelling speeds, for the highest controller step can be obtained from Fig. 2.

Special attention was devoted, when designing the locomotive, to easy accessibility and to facilitating the taking out and putting in of the machinery plant. After removal of the side-wall plates and roof of the engine room, the Diesel engine, generators and apparatus lodged above them are accessible from all sides and can be taken out sidewise or else lifted out from above (Fig. 3). The complete apparatus of the main-current circuit is concentrated in an apparatus casing, placed in the centre below the main frame. This casing is accessible from outside and from below. The driving motors with the sets of wheels and axle boxes can be dismantled from below when the locomotive is placed over a pit, or can be overhauled under the same conditions.

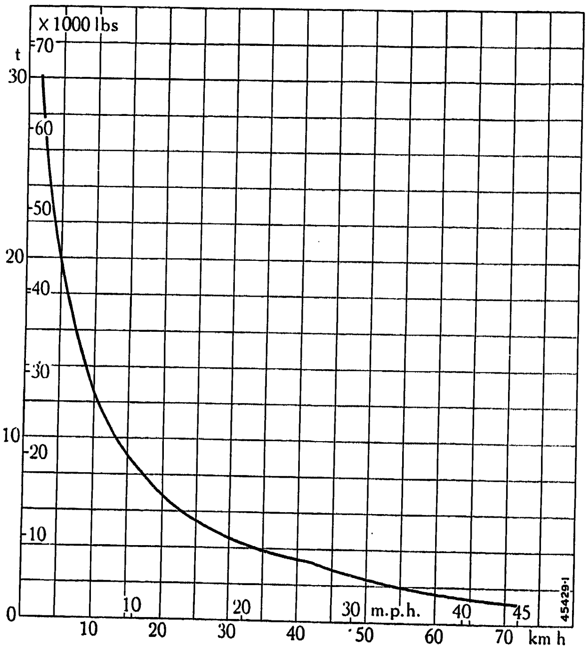


Fig. 2. — Tractive effort-speed diagram for a total output of 660 H. P. and a tractive output of 600 H. P. of the Diesel engine.

The *mechanical part* of the equipment comprises, chiefly, the locomotive cab and the two bogies. The main under frame of the cab is of cast steel; it is in one part and exceptionally strong. It also contains the fuel tanks, the batteries and the sand containers, the channels for the cooling air of the motors, the bogie pivots and the coupling casings and, further, carries the slightly raised driver's cab, at the rear end, and the compressed-air containers. There is a sub-base which is an integral steel casting supported on the main under frame through the intermediary of cork and rubber cushions. This sub-base carries the Diesel engine, generator set, the engine radiators with cooling fans and the blower set for the driving motors, all of which are rigidly bolted to the said auxiliary frame. Further, the front end of the main frame carries the motor-compressor set; on both front ends there are platforms with steps and foot plates for the shunting operators to stand and to allow them to move, without danger, from one side of the locomotive to the other. The covering of the engine room is composed of steel sheets and is designed perfectly weatherproof. The roof and side walls can be entirely removed. To carry out small overhauls and repairs, there are, also, openings with sliding hatches in the roof and numerous hinged doors in the side walls.

The frames of the bogies are also of cast steel. All axles have Timkin roller bearings and each of them is driven by an axle bearing motor through a single reduction gear located on one side. There is a hand brake available, apart from the Westinghouse compressed-air brake which acts on all the eight wheels.

The De La Vergne *Diesel engine* is a six-cylinder machine working to the four-stroke process and with solid fuel injection. With a 318-mm bore and 394-mm stroke, it delivers 660 H. P. at 600 r. p. m. This engine is the result of many years of experience gained in the field of engine construction by the De La Vergne Engine Company, which took up the manufacture of internal combustion engines as early as the year 1893 and built the first Diesel engine in the United States with solid injection, in the year 1917. A special feature of this engine is the slow and uniform combustion process. In this way, it is possible to keep the injection pressure and the peak of the combustion pressure relatively low, and this is a great advantage. The small fuel consumption and the exhaust, quite free of smoke, are the visible signs of the completeness and economical quality of the combustion process taking place in the working cylinders of the engine. The fuel is introduced under pressure to the combustion chambers through the lateral injection nozzles, the feed being controlled by a Bosch fuel pump which comprises a pump element for each Diesel-engine cylinder. There is a Woodward centrifugal governor to regulate the amount of fuel injected, the speed (r. p. m.) being maintained constant for a given position of the governor. Further, the governor can be adjusted from the driver's cab, mechanically, for all speeds between 300 and 600 r. p. m. The Diesel engine is started up by means of the main generator coupled to it, which is connected up as a series motor, to this end, and is then supplied from the storage battery. Stopping the Diesel engine is

also carried out by remote control, by means of a valve controlled electro-magnetically.

There are four tubular radiators by the Modine Radiator Company for recooling the cooling water and the lubricating oil, which are located in the front end of the locomotive. They are built into the side walls, vertically, so that their cooling effect may be independent of the sense of displacement of the locomotive and not influenced by the trailer coaches. There is an electrically-driven vertical shaft fan to ventilate the said radiators.

The *electric equipment* is, mainly, composed of the generator set, rigidly coupled to the Diesel engine; the four driving motors; various auxiliary machines; the storage battery and the apparatus for the main and auxiliary-current circuit. The generator set is of the special design evolved by Brown Boveri for Diesel vehicles and which has proved its qualities in numerous plants. It comprises a 415-kW main generator and a 40-kW auxiliary generator. The armature of the auxiliary generator is overhung on the shaft of the main generator designed as a hollow shaft in order to attain the highest moment of resistance for the lightest weight. The main generator is self-ventilated and is separately excited from the auxiliary generator; it supplies the four driving motors, which are always connected in parallel, the supply being at variable voltage, with a maximum of 600 V. The servo field-regulator regulates in the circuit of the separate excitation in such a way that the desired fuel charge injected is maintained constant, so that at each different speed (r. p. m.) the Diesel-engine output available is utilized to the full and that the engine is never overloaded, under any circumstances. By counter-compounding, the characteristic of the main generator is given such a falling character that the starting current is limited, automatically, to the maximum allowable value. The auxiliary generator is a purely shunt machine. Apart from the separate excitation of the main generator, it supplies the various auxiliary machines and looks after the charging of the storage battery. Its voltage is maintained constant, by means of field regulation, to the value of 125 V, in the range of speed between 300 and 600 r. p. m.

The four driving motors, each for 201-kW one-hour rating at 600 V, are separately cooled and of standard axle-bearing type. Each motor drives an axle through a single lateral spur-wheel reduction gear with a ratio of 15 to 68. They are connected to the terminals of the main generator through a four-pole, electro-pneumatically operated cam switch, four over-current relays and a drum-type change-over switch which is controlled by electro-magnetic valve. In order to attain high speeds, the fields of the motors are shunted in two stages, which operation is carried out by two four-pole electro-pneumatically controlled contactors.

The auxiliary machines comprise:— a 15-kW fan motor of vertical-shaft design which can be regulated in two steps and which drives the fan of the radiators, a horizontal-shaft motor-fan set for separate cooling of the driving motors and a motor-compressor set which can draw in 4250 litres of air per minute and compress it up to 9·5 kg/cm² gauge pressure. All these auxiliaries which are, usually, connected up to the terminals of the auxiliary generator, can be supplied from the storage battery, in an emergency, when the Diesel engine is stopped. The lighting and control-current circuits are connected up straight to the terminals of the battery, as is customary in such cases. This battery consists of 56 lead cells with a capacity of 272 Ah one-hour discharge rating and it is connected to the auxiliary generator, through an automatic charging and reverse-current relay, as soon as the charging voltage is reached.

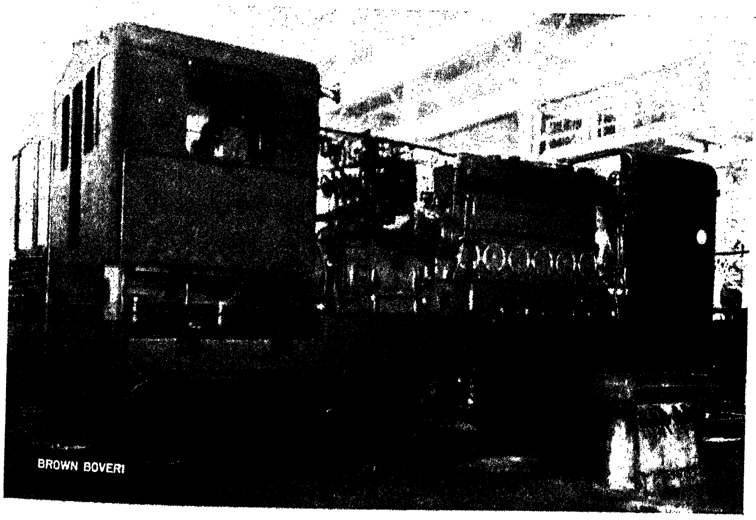


Fig. 3. View of right side with side wall removed.

All the organs requisite to control and supervision of the thermal and electrical equipment of the locomotive are concentrated in the driver's cab. The regulation of the travelling speed is carried out by gradual variation in the speed of the Diesel engine by means of a speed-regulating lever of which there is one on each side of the driver's cab. To set the sense of travel and to reduce the field of the driving motors, there is a common drum controller available. The starting and stopping of the Diesel engine and of the fan motors, as well as the speed adjustment of the radiator fan is carried out by actuating six push-button switches mounted in a common

casing. There are other push-buttons to close and open the control and the lighting-current circuits. When the weather is cold, the driver's cab can be heated by the cooling water.

The locomotive described here differs from all other Diesel-electric shunting locomotives built, up till now, in the United States, not only in the system of electric transmission but also in the four driving motors being constantly connected in parallel, an arrangement made possible thanks to the Brown Boveri servo field-regulator control. The relatively narrow regulating range allowed by the control systems of competitor firms, forces the latter to use series-parallel connection for their driving motors. With this arrangement, the most difficult startings must be carried out with the motors in series which, as is well known, increases the danger of skidding. Further, when going over from series to parallel connections there is an unavoidable complete or, at least, partial interruption of the tractive effort, which may lead to shocks and hunting between the coaches if the start is difficult and may even cause parting of the coach couplings. With constant parallel connection of the motors, on the contrary, there is far less danger of skidding; the start is smooth and gradual, up to the highest travelling speeds. This was made especially evident during the test and demonstration trips. Thanks to the advantageous electrical qualities, this 97-t locomotive can set in motion, on the level, a 4000-t train with 92 heavy freight cars and accelerate it uniformily, a result never yet attained with any other similar locomotive. For this reason, the machine met with general approval from all the railway companies.

(MS 538) *Dr. E. Meyer. (Mo.)*

THE BROWN BOVERI HOT-WATER ELECTRIC BOILER WITH HEAT ACCUMULATOR USED IN CENTRAL-HEATING PLANTS.

Decimal index 621. 364. 3 : 621. 186. 85.

THE utilization of the electric boiler combined with a heat accumulator, in central-heating plants, has the great advantage of allowing the use of cheap night power for heating purposes. Further, the use of night power, exclusively, means that there will always be power available whatever the season of the year and, in many cases, whatever increase there may be in day-power consumption on the supply system.

At the same time, plants of this kind are very advantageous as regards upkeep charges, as no attendance is required and there is no soiling of the rooms or surrounding areas by soot and ashes, a disagreable feature of coal firing. The advantages of such electric plants from the point of view of the economical use of the available power of the country need only be mentioned, in passing.

In the following paragraphs, an electric boiler plant with heat accumulator is calculated and this for the following cases:—

1. An electric boiler of the ordinary type with hot-water accumulator, the initial temperature of which is equal to the initial temperature of the central-heating system.

2. A Brown Boveri electric boiler with hot-water accumulator in an open central-heating system, with or without hot-water preparation for different uses.

3. A Brown Boveri electric boiler with hot-water accumulator in a closed central-heating system with or without hot-water preparation for different uses (heat distribution by hot water under pressure).

The examples calculated are based on the following assumptions:—

Total volume of rooms to be heated	20,000 m^3
Room temperature called for . . .	+ 20° C
Average external temperature in cold winter weather	— 3° C
Extreme external temperature . . .	—10° C

If the plant is to be so dimensioned that there will be a difference of 30° C between the external and internal temperature during 16 hours, while, during the remaining 8 hours, the heat consumption is to be lower by one third, the following figures are reached for the total amount of heat to be used.

The amount of heat per m^3 of room space and per °C of temperature difference is assumed to be 0·43 kcal/h or 0·5 watt respectively.

The total power consumed in the 16 hours will, thus, amount to:—

$$0{\cdot}5 \times 20{,}000 \times (20^{0}\,C + 10^{0}\,C) \times 16$$
$$= 4800 \text{ kWh or } 4{,}128{,}000 \text{ kcal.}$$

During the remaining 8 hours:— $^{2}/_{3} \times 0{\cdot}5 \times 20{,}000 \times 30 \times 8$ = 1600 kWh or 1,376,000 kcal

Total = 6400 kWh or 5,504,000 kcal.

If it be assumed that 20,000 litres of hot water at 90° C have to be prepared, at the same time,

for various other requirements, within 24 hours, an additional heat consumption of

20,000 × (90° C — 15° C) = 1,500,000 kcal or 1744 kWh must be reckoned with.

Thus, the total consumption for heating and hot-water preparation amounts, in 24 hours, to

8144 kWh or 7,004,000 kcal.

If it be assumed that cheap night power is only available during eight hours of the night and the whole heating power has to be supplied during that time, the electric boiler has to be dimensioned for the following output:—

1. For heating purposes:

$$L_1 = \frac{6400 \text{ kWh}}{8 \text{ h}} = 800 \text{ kW}.$$

2. For heating purposes and hot-water preparation:—

$$L_2 = \frac{8144 \text{ kWh}}{8 \text{ h}} = 1000 \text{ kW}.$$

The suitable type of electric boiler to be chosen would have a peak output in case 1 of 900 kW and in case 2 of 1100 kW.

It should be remembered, however, that the external temperature very rarely falls below —3° C. A bigger temperature difference than 23° C is, therefore, of infrequent occurrence and lasts only for a short time. It is, therefore, recommendable, on economical grounds, not to dimension the heat accumulator for the extreme conditions, that is to say for 30° C, but to do so for 23° C, only.

The heating then calls for:—

$$5{,}504{,}000 \text{ kcal} \times \frac{23}{30} = 4{,}220{,}000 \text{ kcal}.$$

The difference between the quantity of heat which can be delivered by the accumulator and the peak power consumption, under unfavourable weather conditions, is

5,504,000 kcal — 4,220,000 kcal = 1,284,000 kcal.

It is, however, possible to cover this lack of heat by switching in the electric boiler during the midday two-hours' rest time, which allows of generating the following amounts of heat:—

1. 900 × 2 × 860 × 0·95 = 1,475,000 kcal.
2. 1100 × 2 × 860 × 0·95 = 1,800,000 kcal.

Thus, the room temperature of 20° C is also maintained when the outside temperature of —10° C persists.

The volume of the accumulator, for the cases specified before, is determined as follows:—

(a) *The heat accumulator in a central-heating plant with an electric boiler of ordinary type.*

The initial-flow temperature of the accumulator is equal to the initial temperature of the central-heating system. The heating of the water in the accumulator is carried out by a steam boiler which supplied a heat exchanger built into the accumulator. The condensate flows back straight to the boiler from the said heat exchanger.

Allowing for an initial-flow temperature of 90° C in the central-heating plant, and for a return-flow temperature of 60° C, the amount of heat to be stored per m³ of accumulator will be:—

$$30 \times 1000 = 30{,}000 \text{ kcal}.$$

A plant of this type is only suitable for accumulating hot water for central-heating systems, where the highest temperature of the water, as mentioned before, attains 90° C. To produce hot water for other uses, at 90° C, it would be better, in a case like this, to use separate boilers with electric-resistance heating.

As calculated before, the total quantity of heat to be accumulated, for central-heating purposes,

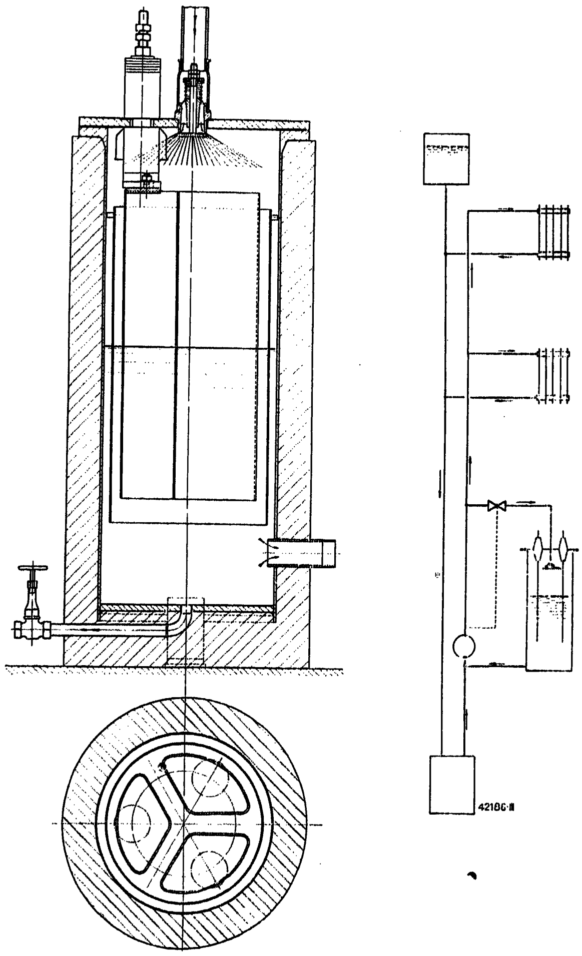


Fig. 1. — Section of a Brown Boveri low-voltage hot-water electric boiler.

amounts to 4,220,000 kcal. This gives an accumulator volume of

$$\frac{4{,}220{,}000 \text{ kcal}}{30{,}000} = 140 \cdot 6 \text{ m}^3.$$

In the present case, it was considered best to put in two accumulators, each of 70 m^3 capacity.

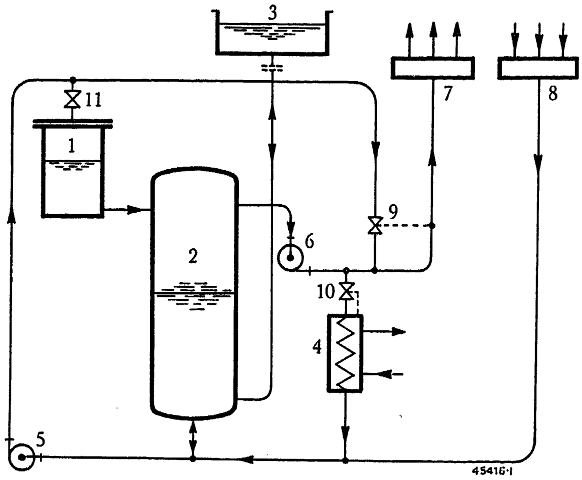


Fig. 2. — Brown Boveri hot-water electric-boiler plant with heat accumulator, open system.

1. Electric boiler.
2. Hot-water accumulator.
3. Expansion tank.
4. Heat exchanger.
5. Circulation pump of heating system.
6. Circulation pump of accumulator.
7. Outgoing header.
8. Return header.
9. Regulating valve with thermostat control.
10. Regulating valve with thermostat control.
11. Output regulating valve.

(b) *The Brown Boveri hot-water electric boiler for heating purposes and hot-water production combined with an accumulator in an open central-heating system.*

As is known, the Brown Boveri hot-water electric boiler works at the saturation temperature of the water which corresponds to the height of the water column of the central-heating system (Fig. 1). In this way, it is possible, on the one hand, to accumulate the water at a higher temperature and, thus, to diminish the volume of the accumulator, considerably and, on the other hand, to use the hot-stored water in a heat exchanger, to generate hot water for other uses. Fig. 2 shows a hot-water plant of this kind. A detailed description of the Brown Boveri hot-water electric boiler is not given here, the reader being referred to the article in the November number, 1936, of The Brown Boveri Review.

When the electric boiler is working, the return-flow of water comes from the header 8 and flows, partly, to the accumulator 2 and, partly, through the circulation pump 5 to the electric boiler 1 and the remainder through the regulating valve 9 to the outgoing header 7. The quantity of water flowing to the electric boiler is governed by regulating valve 11. The hot water flowing from the boiler reaches the accumulator 2 and from here is carried by pump 6 to the initial-flow pipe of the central-heating system and to the heat exchanger 4. This hot water is mixed with a definite amount of return-flow water so that the temperature in the initial-flow pipe, regulated by thermostat 9 remains constant. Part of the hot water flows through the heat exchanger and gives up its heat to the water used for other purposes. If none of the latter is wanted, momentarily, the temperature rises in the heat exchanger to a maximum value at which thermostat 10 cuts off the inflow of hot water. If the accumulator is fully charged, a thermostat in its lower part begins to close regulating valve 11 so that the load of the electric boiler is reduced and may even be entirely stopped. If the electric boiler is cut out, only as much hot water is taken from the accumulator as is required to bring up the temperature of the return-flow water to the value for the outflow. When the accumulator is discharged, the electric boiler is started up automatically again, and the hot water it delivers can be utilized immediately, through the medium of pump 6 to feed the central-heating system and to produce the hot water wanted for other purposes.

If a practical case is taken the following figures are obtained: —

Assuming a building of about 22 m height, the temperature of the hot water in the electric boiler will be about 135° C.

If the return-flow temperature attains 60° C, the temperature drop is 75° C.

On the basis of the consumption of calories in 24 hours already carried out, the volume necessary for the accumulator will be: —

Energy consumption for central heating	4,220,000 kcal
Energy consumption for hot-water production	1,500,000 kcal
Total	5,720,000 kcal

which gives an accumulator volume of: —

$$\frac{5{,}720{,}000 \text{ kcal}}{75 \times 1000} = 76 \cdot 3 \text{ m}^3. \tag{1}$$

If the accumulator is only used for central-heating: —

$$\frac{4{,}220{,}000 \text{ kcal}}{75 \times 1000} = 56 \cdot 3 \text{ m}^3. \tag{2}$$

For case 1, an accumulator of 78 m^3 and for case 2 one of 58 m^3 would be suitable.

(c) *The Brown Boveri electric boiler with hot-water accumulator, in a closed heating system.*

The Brown Boveri electric boiler is, also, very suitable for a closed heating system working under an increased pressure, such as is often used nowadays for distributing big quantities of heat.

Let it be assumed that the plant works at a pressure of 12 kg/cm². As shown in Fig. 3 the central-heating system is connected to the pressure system through a heat exchanger. The second heat exchanger shown is for producing hot water for other purposes.

In a plant like this, the expansion tank of the system is designed as an accumulator. The electric

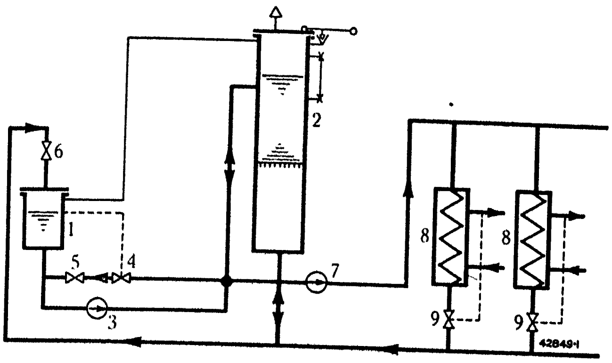


Fig. 3. — Brown Boveri hot-water electric-boiler plant with an accumulator in a closed heating system.

1. Electric boiler.
2. Accumulator.
3. Circulation pump for accumulator.
4. Pressure-regulating valve.
5. Hand-regulating valve.
6. Power-input regulating valve.
7. Circulation pump of heating system.
8. Heat exchanger.
9. Automatic regulating valve with thermostat control.

boiler works on the same principle as in an open system. The pressure in the boiler, that is, in the system, is regulated, however, by a pressure regulator which controls the volume of water flowing from the boiler. A detailed description of a plant of this type is given in the article, already mentioned, which appeared in the November number 1936, of The Brown Boveri Review.

At a pressure of 12 kg/cm², the initial-flow temperature of the system is 190° C. With a return-flow temperature of 70° C, the volume of the accumulator will be:

$$1. \quad \frac{5{,}720{,}000 \text{ kcal}}{120 \times 1000} = 47 \cdot 6 \text{ m}^3.$$

$$2. \quad \frac{4{,}220{,}000 \text{ kcal}}{120 \times 1000} = 35 \text{ m}^3.$$

The accumulator suitable would be of 48 or 36 m³, respectively.

Summary.

For the three cases calculated, the following accumulator volumes are reached for the same power conditions:—

1. *Without hot-water generation for special purposes:—*

(a) Hot-water plant with electric boiler (case 1) 144 m³.
Volume of accumulator 2 × 70 m³.

(b) Brown Boveri hot-water electric boiler with open expansion tank (case 2).
Volume of accumulator 58 m³.

(c) Brown Boveri hot-water electric boiler in a closed system (case 3).
Volume of accumulator 36 m³.

2. *With hot-water generation for special purposes.*

(a) As said before, a hot-water plant is not suitable for the preparation of hot water for special purposes.

(b) Brown Boveri hot-water electric boiler with open expansion tank (case 2 a).
Volume of accumulator 78 m³.

(c) Brown Boveri hot-water electric boiler in a closed system (case 3 a).
Volume of accumulator 48 m³.

The example given here refers to a big building (hotel, hospital, etc.). It should be mentioned, however, that a hot-water electric boiler like this is also suitable to small buildings. For an eight-dwelling house, for example, the situation would be as follows:— electric-boiler plant to be dimensioned for an output of 180 kW (central heating only) or 220 kW (central heating and water preparation).

Volume of accumulator:—	case 1 . . .	35 m³
	,, 2 . . .	15 m³
	,, 2 a . .	20 m³
	,, 3 . . .	7 m³
	,, 3 a . .	10 m³.

Such an accumulator as the one required in case 3, is easily lodged in a dwelling house. An accumulator of 35 m³ capacity (case 1) which is abt. 7 m long and has a diameter of abt. 2·5 m, could hardly be lodged in the basement of a dwelling house, so that a special chamber would have to be provided, which increases the cost of the plant considerably.

Finally, it should be remarked that the Brown Boveri electric boiler, thanks to the high temperature of the hot water generated, in the open system, can also be used to produce water for other purposes, as, for example, for washing and cooking apparatus, so that one single boiler can be used to produce the necessary calories for a dwelling; it works under one pressure only, corresponding to that in the central-heating system.

Connections according to cases 3 and 3 a, respectively, are also quite suitable to produce hot water for remote-heating plants.

The Brown Boveri hot-water electric boiler is built for outputs of 50 to 2000 kW and voltages up to 1000 V.

(MS 542) *E. Soldati. (Mo.)*

A. C. AND D. C. CONTACTORS WITH CONTACTS IN AIR.

Decimal index 621. 316. 53. 064. 24.

THE switch controlled by electro-magnet, the "contactor", has become, to-day, an indispensable element of electric switching and controlling devices of every kind. Severe demands are made on the adaptability of these contactors according to the kind of current, the service conditions, switching duty, etc. they are called on to work to. The following

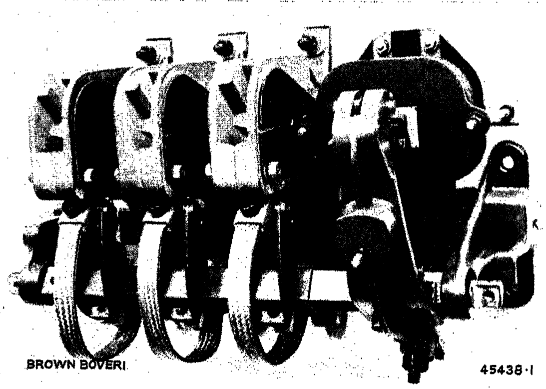


Fig. 1. — Three-pole A. C. contactor, Type A-3N. 3S.-5 (standard design with blow-out, size 5).

description of the new A. C. and D. C. contactors, Types A and C, with contacts in air, will show how all these manifold requirements have been successfully met by the creation of a series of contactors of modern designs.

The most striking feature in the design of these contactors is their construction chiefly of metallic elements only with a rugged *steel bar of square section* as supporting organ for the contactor as a whole with all auxiliary contacts and accessories (in background of Fig. 1). The square steel bar is insulated from the current-carrying parts and is secured to the switchgear frame by means of two brackets. The latter also serve as bearings for the spindle on which the moving contacts are secured (foreground of Fig. 1). The design is characterized by *great mechanical strength, easy mounting, perfect accessibility to all parts* and *unhindered access for bringing in the leads* to the terminals.

A. C. and D. C. contactors are absolutely similar in design and made up of the same elements, apart from the closing magnet and coil. According to the number of poles, there are one, two, three or four vertical supports secured on the steel bar of square section, the upper part of which supports carry the fixed contacts which, according to requirements, have sparking chambers and blow-out coils. The lower part of the support carries the connecting terminal, which is insulated from the upper part, and the flexible connection to the moving contact.

The main contacts are made of massive copper, silver-plated. Both fixed and moving contacts roll on each other, *practically without friction*, when closing and opening; this preserves the contacts while sufficing to keep them sufficiently clean. The closing and opening power thus saved, allows of using closing coils of astonishingly low consumption. Thus, for example, the coil of a contactor of 40—50 A rating only consumes about 13 watts in closed position, when supplied by D. C. and only about 6 watts when supplied by A. C. at 50 cycles. The shape of the contacts is such that wear and oxidization are limited to the external parts while those parts through which current flows, under ordinary service conditions, are always clean and whole. The contacts are very accessible and easy to change.

The moving contact is connected to its terminal by a woven copper conductor. The great flexibility of the latter gives it a long life even under very frequent switching duty. The blow-out coils, delivered on request, are of turns of copper ribbon wound over an iron core and secured to the support carrying the fixed contact. The pole plates of the blow-out magnet can be rotated, so that the sparking chamber can be raised without any dismantling, thus allowing of supervising the contacts.

In the case of A. C., the magnet system comprises a core of laminations of great permeability, while for D. C. the core is a massive soft-iron piece. The front surface of the core is very precisely machined and the corresponding armature, which is also machined (and either laminated or solid) applies on this surface. The armature is loosely cradled which assures its exact application on the surface of the magnet core. The magnet coil is carefully impregnated and so designed that it can stand up to damp surroundings, vibrations and high temperatures, continuously. There are short-circuited coil turns which suppress annoying humming noises in the case of A. C. coils. A recall spring on the moving part allows of perfect functioning even in inclined positions, up to 15^0, so that these contactors can be used, perfectly, on vehicles (ships, locomotives) or other mobile plants.

All metallic parts are treated against oxidization, the insulating materials utilized are not hygroscopic and all screws are so secured that they cannot work loose.

The disposal of the contactors in any plant depends, on the one hand, on how they are mounted and, on the other, on the frequency of switching. As regards *mounting*, there is a distinction between

mounting in totally-enclosed casings, in ventilated cubicles or in open frames. Thus, for example, the rated current of the smallest type of contactor is 40 A in a totally-enclosed casing, but is 45 A in a ventilated cubicle and reaches 50 A in an open frame.

According to the *nature of service* a distinction is made beetween *continuous service* with a maximum of 100 switchings per hour, *intermittent service* with up to 300 switchings per hour and

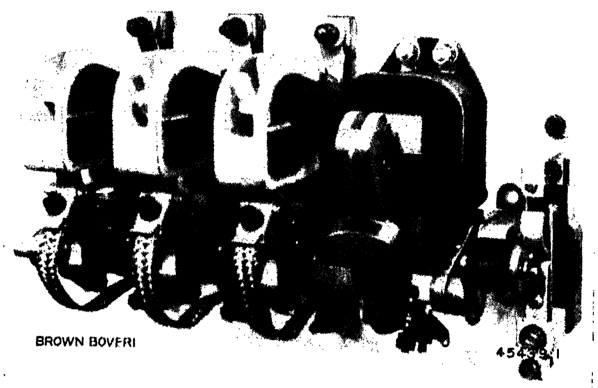


Fig. 2. — Three-pole A. C. contactor (standard design with blow-out, size 3) with built-on auxiliary contact.

severe service with more than 300 switchings per hour. As the frequency of switching per hour increases, it is obvious that the rated current must be somewhat lowered. For a big number of switchings per hour, the contactors are mechanically strengthened, the blow-out effect reinforced and the bearing points specially lubricated. By so doing, it was made possible to adapt one and the same fundamental design to the whole range of requirements met with in practice.

The design of the *auxiliary contacts* (Fig. 2) has been the subject of careful investigation, on the principle that auxiliary contacts are just as important as main contacts. In the smaller contactors, the auxiliary contacts are located, in part, between the main poles and the remainder outside one of the bearing brackets. In cases where a change-over contact is required, a closing as well as an opening contact must be used.

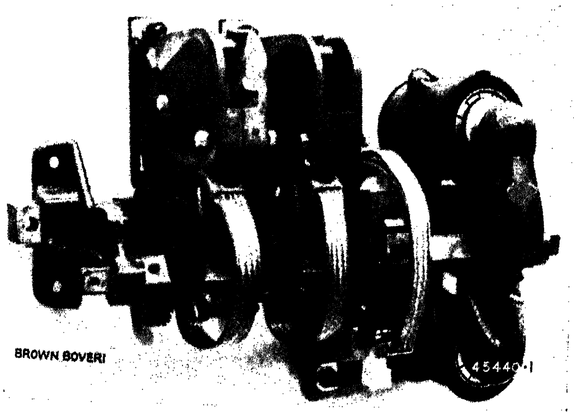


Fig. 3. — Two-pole D. C. braking contactor.

Braking contactors for D. C. (Fig. 3). These contactors make the control for the electric braking of D. C. motors a simple matter. The contactors are equipped, here, with a double system of main contacts:— the working contacts (a) which close and open the service circuit, in the usual manner, and the braking contact (b) which is closed when the working contact is open (Fig. 4). By means of this contact, the armature current circuit of the controlled D. C. motor is closed over a braking resistance (d). A holding magnet, the coil (c) of which is supplied with the braking current, produces an efficient contact pressure in the braking position, as well, as long as braking lasts.

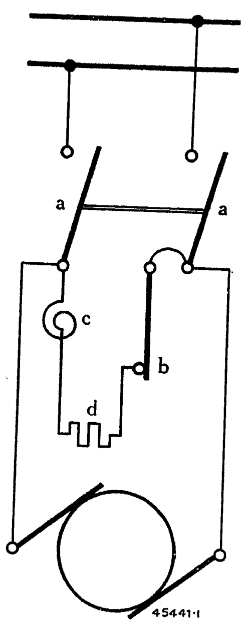


Fig. 4. — Diagram of connections for using a D. C. braking contactor.

Braking contactors are only built for D. C. and with one or two poles. The working contacts always have blow-out coils.

Mechanical interlocking of two contactors (Fig. 5). For a reversing process or other requirements in which two contactors are always alternatively closed, contactors of the same

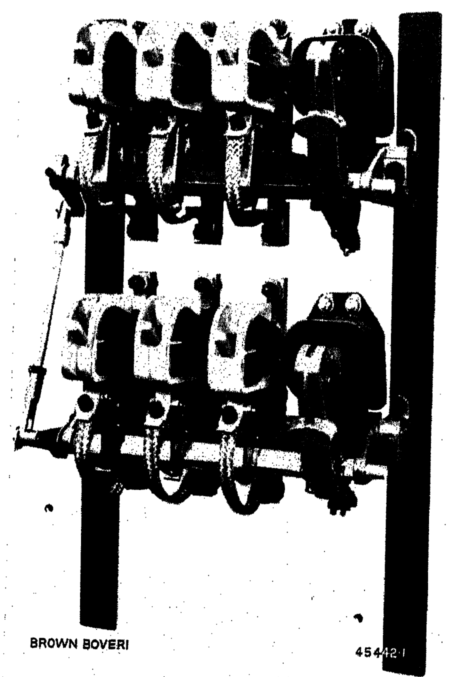


Fig. 5. — Mechanical interlock of two A. C. contactors.

size can be mechanically interlocked in pairs. A simple lever system is used, by means of which the spindles of the super-imposed contactors are connected together, so that when one is closed the other cannot be operated. This interlock increases the reliability of these kinds of control.

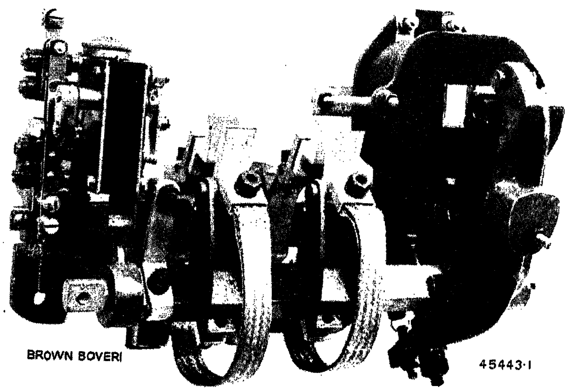


Fig. 6. — Two-pole A. C. contactor with standard, built-on time supervisor.

The most important auxiliary devices, especially in the case of starting controls, are the so-termed *acceleration relays* which supervise the automatic and successive switchings of starting contactors or similar apparatus. There are two kinds of acceleration relays:— those *dependent on time*, or chrometrical, and those *dependent on current*, or amperemetrical (time and current supervisors).

The acceleration relays are, always, built on to the contactor, their action depending on the movement of the said contactor. Thus, the closing movement of the contactor frees the relay and after the time lag set for (or in the case of current supervisions after the current has fallen to the value set to) the relay armature drops and energizes the contact system.

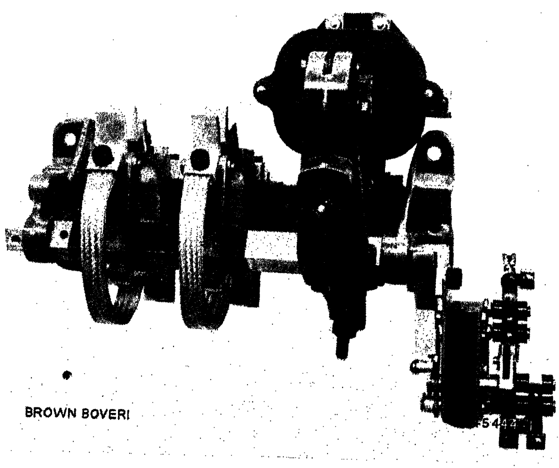


Fig. 7. — Two-pole A. C. contactor with time supervisor mounted reversed.

When the contactor is opened, the relay armature is raised again and maintained in this position until the next switching process takes place.

The *acceleration relay dependent on time* (time supervisor, Fig. 6) is provided with a piece of

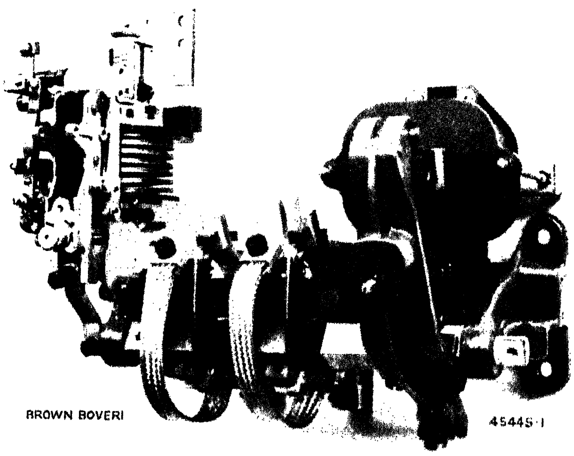


Fig. 8. — Two-pole A. C. contactor with built-on time supervisor.

clockwork, in a metal casing and with a non-oxidizable steel spring which, as soon as the contactor has closed, actuates instantaneously a closing, opening or change-over contact when a certain fixed time has passed. They are built for a time lag which can be set between 0·2—60 seconds. There is a screw with setting head to allow of adjusting the desired time lag. When the contactor opens, the relay contact is brought back to its rest position and the clockwork wound up again, simultaneously.

The time supervisions can also be built reversed (Fig. 7), that is to say, the clockwork can be wound up at the closing of the contactor and freed to run when the contactor opens. In this case, the contact device is actuated with the adjusted time lag after the contactor opens.

The acceleration relay dependent on current (current supervisor Fig. 8) is composed of a current coil and a relay armature controlled by it. The coil can be wound for current ratings between 25 and 1000 A. When the contactor is open, the relay armature of the current supervisor built on to it, is maintained raised. When the contactor is closed the relay armature is freed; at the same time the relay coil is energized by current, which causes the armature to be held up, until the current falls, gradially, during the process being supervised, until it reaches a minimum value set for. The relay armature, once fallen, actuates a closing, opening or change-over contact, as in the case of the time supervisor, by means of which the next contactor, for example, is controlled. When the contactor opens, the relay armature is raised again.

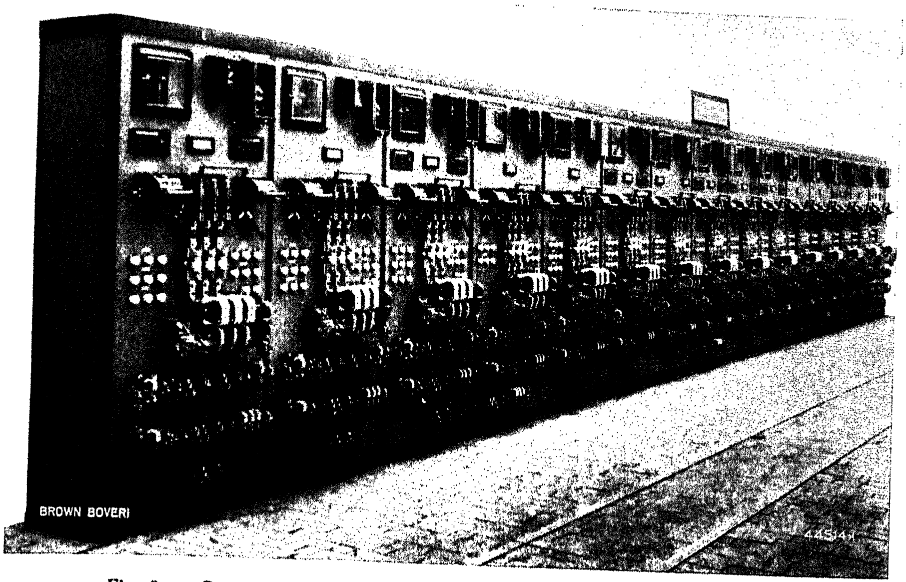


Fig. 9. Contactor panel for the drive of a big, newspaper rotary machine.

In this design, the current supervision acts as a minimum-current relay; with, practically, the same construction, it can, however, be designed as a maximum-current relay. There is an adjustment screw for the setting of the current strength at which the relay is to act.

This description of the contactors, which can be built with one to four poles and for current ratings up to 950 A according to the kind of current and nature of service, shows how adaptable they are to different switching and service conditions and how easy it is to combine different controls with them. The close combination of contactor and acceleration relay, for example, saves control leads and interlocks and also enhances the reliability of the device. Contactors to produce mechanical interlocks and contactors for braking can be combined to give similarly advantageous results. It is also easy to replace two two-pole contactors which have to be controlled simultaneously by a single four-pole one. It is this reduction in interdependance (which interindependance is the weak feature of every automatic equipment) which makes the new series of contactors valuable. The series is so designed that it goes far to satisfy the requirements of practical service as regards simplicity and safety, which requirements set practical limits on the development of all combined controls. Experience gained in various plants and including those with severe service conditions has proved the valuable qualities of the new contactors.

(MS 545) *S. Hopferwieser. (Mo.)*

SOME COMMENTS ON FREQUENCY AND POWER REGULATION.

(Conclusion.)

Decimal index 621. 316. 726 : 621. 316. 728.

III. THE PART PLAYED BY THE TURBINE GOVERNORS.

In the present stage of development, the frequency regulators and the electric output regulators must act indirectly on the turbine governors, thus causing the governor characteristics to be modified through the agency of the small speed-regulating motors. The oil distribution slide valve on the servomotor, in the case of hydraulic turbines, and on the valves, in the case of steam turbines, is, chiefly, subjected to the action of the centrifugal governor. The electric regulators will, thus, only produce an effect with a relatively considerable time lag. As was explained before, the distribution of the load, at the first moment of a fluctuation, will, therefore, take place unhindered, under the effect of the kinetic energy stored in the pole wheels and of the reaction of the centrifugal governors of the turbines. The effect of the kinetic energy and of the displacements resulting therefrom is inevitable and necessary. On the other hand, the inopportune intervention of the centrifugal governors might be absolutely suppressed if the electric regulators were made to act straight on the distribution slide valves, the centrifugal organ being simply retained as an element of safety. The interlocks of the electric regulators mentioned in the previous paragraph would become effective from the very first moment, suppressing all tendencies for vagrant regulation. The adaptability of electric regulators is so great that, at a first glance, there would seem to be no practical difficulty in combining them with the turbine governors. This combination only calls for a certain collaboration of the electrical and mechanical manufacturers, which has already been carried out by Brown Boveri, and which has allowed of bringing out a steam-turbine governor controlled by an electrical regulator. Further, Brown Boveri has improved the governors of its turbines by giving them the possibility of modifying their governing characteristic when running, as in the case of hydraulic

turbines. This is a very valuable property as it allows of the machines adapting themselves rapidly to a service the conditions of which are characterized by sudden fluctuations due to overloads caused by consumers or by a power station failing.

Of all the regulating systems considered, the last one described here with its frequency and power regulations, combined with limitations by the frequency, would seem to be the most satisfactory. In practice, there are certain difficulties due to economic considerations inherent to private distribution networks and also due to the aptitude of the power stations to regulate themselves.

This system is recommendable for the interconnection of distribution networks. In the interior of the distribution networks themselves, however, a distribution of the output among the power stations

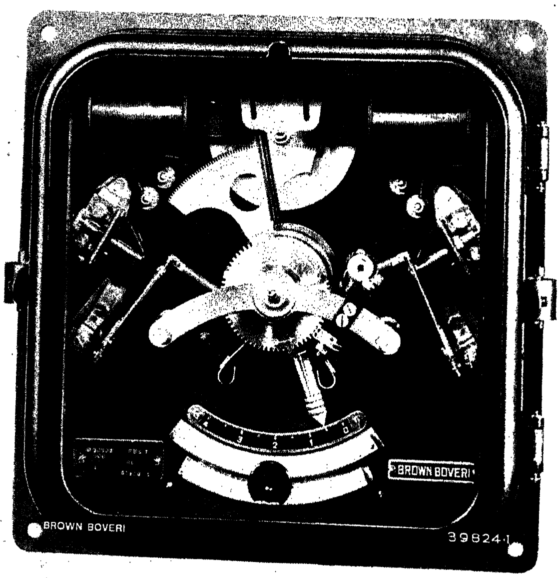


Fig. 7. — Frequency regulator.

making up the system may take place, because the said distribution depends on the characteristics of the power stations involved. The stations regulating the frequency for the particular consumption centre will then, alone, be subjected to the combined regulation necessary for the system. The Brown Boveri regulating apparatus which can meet the various eventualities has been designed so as to require as few organs as possible and to make use of apparatus, such as the quick-acting voltage regulator which has years of reliable service behind it.

IV. THE APPARATUS.

All the regulators are very rugged in design which eliminates danger of breakage while retaining the precision of a measuring instrument. Fig. 7 shows the design. Without going into constructive details, we would recall, here, with the help of Fig. 8, the chief elements which go to make up the regulator.

The motor system is composed of the two fixed excitation coils a and b and the moving armature in the shape of a simple aluminium drum c. The torque it exerts on the shaft is opposed by that of counter-

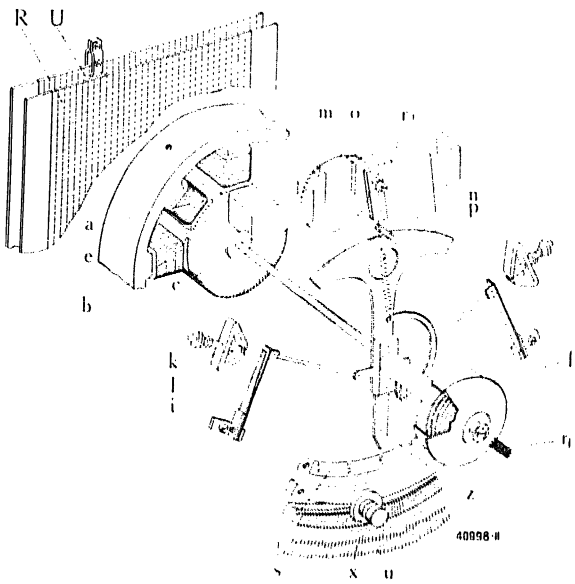


Fig. 8. Principle of regulating regulator.

spring f the tension of which can be adjusted by nut r_1. The torque of spring f, which is, necessarily, not constant, establishes a fundamental characteristic which can be modified down to zero by means of an additional spring n which is controlled by nut r_2; thus, the regulator characteristic can be made flat. The control system comprises a set of fixed contacts k and moving ones i fixed rigidly to the motor spindle and subjected to the combined effect of a recall and damping device. This device is represented by disc o rotated by sector p between the poles of electro-magnet m. Usually, the electro-magnets balance each other, but when one or other of the control contacts closes, the action of the electro-magnets is modified so that disc o exercises a counter torque to the motor torque, producing in this way, a recall effect. Thus, the regulator acts in impulses, the number and duration of which are in function of the deviations between the real values and those desired and also of the damping and recall qualities, values which can be set independently of one another by simple resistances. These various factors:— torque, incline of governor characteristic, damping, recall, all of which can be adjusted to very easily, make the regulator very flexible, which allows of adapting it to a great variety of characteristics met with either on the machines themselves or on the systems.

All the regulators used:— voltage regulators, frequency regulators, power regulators, balancing regulators have got this same fundamental design and only their electrical connections differ.

(a) *Frequency regulators.*

Frequency regulators on three-phase systems are connected up as shown in the diagram of Fig. 9. The excitation winding is divided into two parts connected in series, one with a capacity and the other with a choke coil. At the fundamental frequency, which must be maintained constant and be adjustable by means of the choke coil, the torques produced on the drum by the capacity and induction systems are in equilibrium. If the frequency varies, the capacitive system reacts thereto in direct ratio to the frequency while the inductive system reacts in inverse ratio to the frequency. Thus, the two systems add their effects imparting great sensitivity to the regulator and also great stability when the connections in question are used. In reality, the insensitivity of the apparatus is of the order 2/100 of a cycle. As to the behaviour of the frequency itself it can be held to with a margin of $\pm$ 1/10 of a cycle. However, a guarantee of this high order must be given with circumspection as it is greatly dependent on the characteristics of the prime movers.

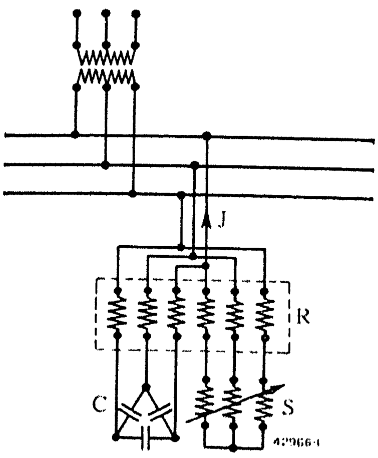


Fig. 9. — Frequency regulator.
C. Capacity.
R. Regulator.
S. Adjustable choke coil.

(b) *Regulation of power.*

This regulator to constant power, must, obviously, be mounted in wattmeter connection. The power to be held to can be adjusted by the tension of the main spring which has a kilowatt scale.

(c) *Balancing regulator.*

The duty of this regulator is to distribute the power required for the system, equally or in given proportions, among the various machines in a power station taking part in the regulation. Usually, a power station regulates with several machines in parallel and there is, therefore, a problem of load sharing to be solved. The balancing regulators are put in to measure the power outputs and to compare them. There are different ways of making this comparison, among others by using the system of connections employed with quick-acting regulators and termed "polygone" connection. This is shown in Fig. 10. The regulators exercise mutual influence without any time lag. As to the amounts of power supplied by the various machines, they can be estimated directly, either at the alternator terminals (Fig. 10) or by utilizing any other method which gives a correct measure of the power delivered. A direct measure of the power can, always, be made in the case of the regulation with steam turbines which react with little time lag to the governing impulses coming from the governors.

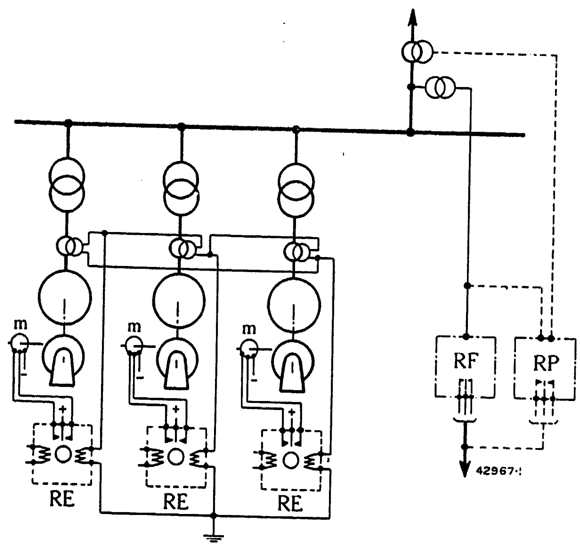


Fig. 10. — Fundamental diagram of frequency or power regulation with balancing regulators.

RE. Balancing regulator.
RF. Frequency regulator.
RP. Power regulator.
m. Motor controlling the turbines.

This system is not so suitable to hydraulic turbines, as the inertia of the water must be reckoned with, a factor which increases as the head of water of the station is lower.

Fig. 10 shows, clearly, how the balancing regulators act. The regulators, already described, RF (frequency) and RP (power) act directly on the various sets which, however, react differently according to their own characteristics. Therefore, circulating currents will be set up in the windings of the RE regulators (balancing regulators) and these regulators will regulate each machine in the desired sense until these currents have been suppressed, that is to say until the various machines are equally loaded or are loaded to some desired porportion, which can be set to.

(d) *Regulators for power regulation with limitation by frequency.*

As far as design goes, this type of regulator differs little from the others. It is generally as shown in Fig. 11 in which the contact system is replaced

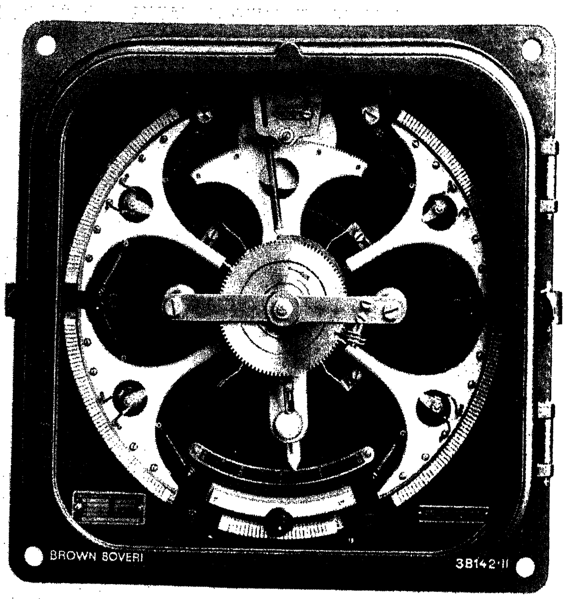


Fig. 11. — Combined regulator, frequency-power.

by sectors. These sectors control potentiometers indispensable if this regulator is to be used in the ordinary way, in common with a power regulator, according to a program, as will be explained. The chief constructive difference is the presence of two motor systems. The first one, dependent on power, acts directly on the motor spindle, while the second, subjected to the frequency, acts on the said spindle through the intermediary of a kind of differential with springs, the tension of which can be set, as desired, fixing the limits of frequency between which the regulation to power output can take place.

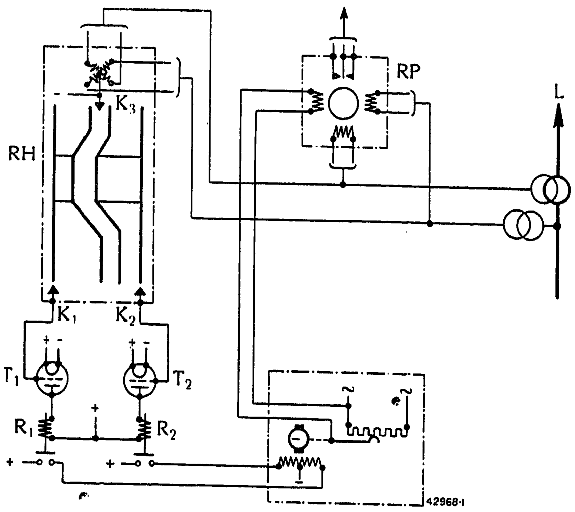


Fig. 12. — Apparatus for power regulation, to program, with limitation by frequency.

RH. Program regulator. RP. Power regulator. T_1, T_2. Amplifying lamps. R_1, R_2. Control relays. L. Line.

Within these limits the frequency torque is zero but when the frequency exceeds them it acts on the motor spindle suspending the action of the power system until such time as the frequency has been re-established. There are no surges at all at the passing from power to frequency regulation.

(e) *Apparatus for power regulation to program with limitation by the frequency.*

This apparatus is shown, diagrammatically, in Fig. 12. In principle, it is composed of the power regulator with frequency limitation, RP, and of a time regulator, RH. The duty of the latter is to dictate to the power station the power distribution program to be held to on one or several distribution lines. It is a simple recording instrument working through the intermediary of two amplifying lamps, T_1 and T_2. The program set for is drawn on the recording strip of paper moved by clockwork, in the usual way. It is limited by two parallel lines between which negatively polarized pointer K_3 slides along. The two parallel lines are connected, from place to place, by transversal lines to the two straight lines along the edge of the paper strip and on which two other pointers glide, K_1 and K_2. All the lines are drawn in in graphite and, thus, form two distinct systems of conductors. The apparatus works in the following way:—

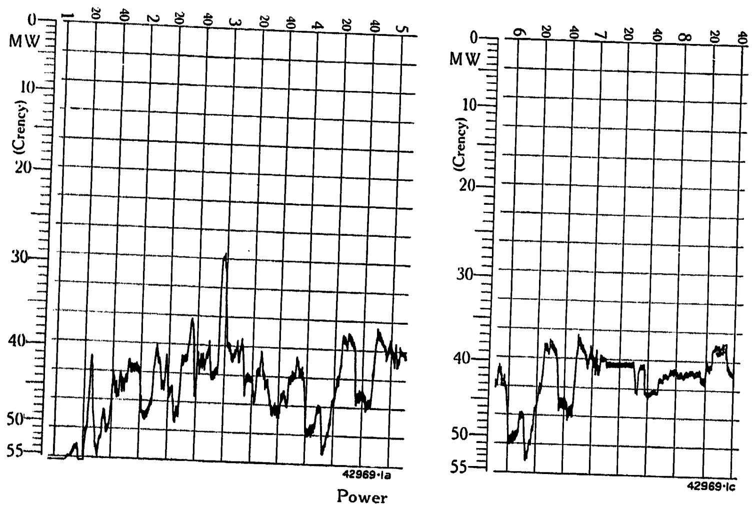
When the system is stable, that is to say when line L transmits the amount of power set for, the pointer K_3 is between the two lines. The circuit is closed by the coils of relays R_1 and R_2 which are, therefore, excited. The strip of paper of RH continues to run. At a given moment the pointer K_3 will come into contact with one or other of the program lines. The result will be to impart the negative voltage of K_3 (through the intermediary of one of the line systems and of pointers K_1 or K_2) to the grid of one or other of the two lamps, the filament-plate circuit of which will be broken. The corresponding relay will fall, thus beginning a regulating operation by making the potentiometer of the regulators RS move. This displacement goes on until pointer K_3 has regained its position between the program lines, the pointer dependent on one system measuring the power on the line. If the frequency drops during regulation or if it increases too much, a "regulation to frequency" is substituted automatically for the power regulation. The regulator RP is, then, subjected to the "frequency" motor system. Once the frequency is re-established, the program is taken up again automatically.

As far as the combined regulation of frequency and power are concerned, it is easy to attain the desired result by a judicious association of the different types of regulator. Finally, it will be noted

that, for frequency, up till now, there has only been a question of regulation of momentary values, with a view to distribute power output, and not for the distribution of the synchronous time, which is only an accessory object. However, frequency regulation to this end alone is, sometimes, carried out, but, then, to average frequency. Differential organs are, then, made use of, dependent on two clocks, one of which runs synchronously and the other astronomically, and which can act directly on the turbines or on the adjustable systems of the frequency regulators, themselves.

V. PRACTICAL RESULTS.

The most important of all the regulating equipments delivered up till today by Brown Boveri is that put into the Kembs Power Station of the Energie Electrique du Rhin. This station contains five sets of, each, 32,500 kVA, working through step-up transformers on lines at 150 and 220 kV. The problem to be solved was to allow the Kembs station to regulate either to constant frequency in the limits of ± 0·1 cycles or to variable power within the limits of 1000 kW according to program with supervision by the frequency. It was particularly difficult to solve these problems, as the prime movers were low-head hydraulic turbines and, further, were of the propeller type, the characteristics of which varied from unit to unit and also according to the head of water available. On account of the, relatively, slow reaction of the turbines, certain devices had to be used which, in conjunction with the adjustable qualities of the regulators, allowed of meeting the requirements of frequency and program maintenance and permitted of suitable load distribution, a factor of great difficulty in the Kembs station. The oscillograms of Fig. 13 which give a comparison between hand and automatic regulation were recorded in similar conditions and on these same machines. This figure shows what excellent results were attained by the automatic regulation. Thus, during one night, and between 1 and 5 in the morning, Kembs running in parallel with the 220-kV system took over the regulation of the frequency. During this period the power recording-strip of paper showed considerable fluctuations between 30 and 55 MW. The frequency strip, nevertheless, remained within very close limits, less than 1/10 of a cycle, that is to say with a margin of 100 % of the guaranteed figure. It should, further, be noted that the average is almost a straight line, proving the stability of regulation. From 5 o'clock onwards, Kembs, still in parallel with the system, ceased to regulate the frequency but regulated to power output and this by hand regulation. From this moment, the frequency oscillogram looses its constancy. The frequency and power records, the latter of which varied less, as shown in the figure, are sufficiently striking to require no comment here.



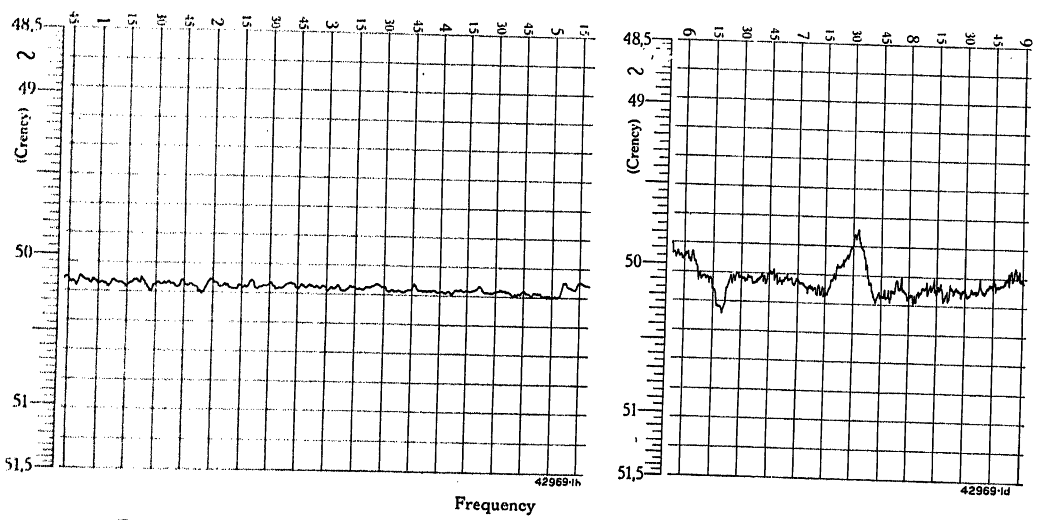


Fig. 13. Comparative oscillogram of automatic and hand regulation of frequency with corresponding power oscillogram.

Another similar equipment is that delivered to the Barbablanca Power Station in Peru. This plant has two 16,000-kVA generating sets with Pelton water-wheel drive. This is a high-head plant, called on to cover load peaks and regulate the frequency.

VI. CONCLUSION.

We have only indicated, here, the general lines of the very actual problem of frequency and power regulation which gets more complicated as the interconnection of systems is further intensified. We have examined the different aspects of the problem in simplified form, but to which a good number of practical cases can be, finally, reduced. There will be other aspects of this problem in the future, but there is every probability that future arrangements between the supply companies will, finally, lead to a general stabilization of the problems. It will be the manufacturer's duty to follow closely the evolutions of this problem and to bring out apparatus to meet the various requirements, as they appear. However, in the place of entirely new apparatus, the course followed by Brown Boveri of building regulators sufficiently adaptable to meet the different conditions imposed would seem to be the right one. There is a great advantage in pursuing this course, as it means working with elements and organs which have been thoroughly tested and tried out by years of practical experience.

(MS 533) *F. Werthmann. (Mo.)*

NOTES.

The Brown Boveri photo-electric smoke indicator.

Decimal index 621. 317. 39. 082. 2 : 662. 613.

ANY disturbance of good combustion conditions in boiler plants is made manifest by the sudden production of smoke. It is, therefore, indispensable that, in a well-run boiler house, a careful check be kept on the exhaust gases, in order to determine the presence of smoke therein. Some large power plants go to the length of placing a man on the roof, whose sole duty it is to notify the operating staff, immediately, of the appearance of smoke at the stack outlet. Apart from the cost involved, such a procedure has the disadvantage that it is not possible to determine directly which, of a number of boilers served by a common stack, is responsible for the smoke.

The Brown Boveri photo-electric smoke indicator is a simple and entirely reliable device for indicating the smoke density at any given point of an exhaust duct. It consists, essentially, of a luminous source, located on one side of the duct, and a photo-electric cell, on the other, which is connected to a sensitive milliammeter. Variations of the smoke density cause corresponding variations of the photo-cell illumination, and, therefore of the photo-electric current, so that the deflection of the instrument is a measure of the smoke intensity.

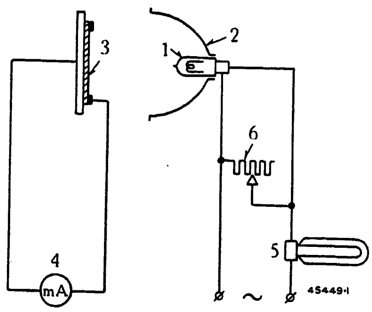


Fig. 1. — Principle of the Brown Boveri photo-electric smoke indicator.

1. Lamp.
2. Parabolic reflector.
3. Photo-cell.
4. Milli-amperemeter.
5. Iron-wire resistance.
6. Adjusting resistance.

The device is shown diagrammatically in Fig. 1. The light radiating from the concentrated filament of the lamp 1 is reflected by the parabolic mirror 2 as a parallel beam on the photo-electric cell 3. The said cell consists of a specially-selected rectifier selenium photo-element, which is characterized by the fact that it generates a current which is proportional to the illumination intensity, within the measuring range of the apparatus and without requiring any auxiliary current supply. Assuming constant intensity of the luminous source, the deflection of the instrument is, therefore, a measure of the opacity of the intervening space. Usually, the instrument dial is divided into three panels, the first panel being black, the second one grey, and the third one white, corresponding to the three conditions «dense smoke», «light smoke» and «no smoke». In addition thereto, there is a finely-graduated scale enabling an accurate measurement of the smoke intensity in opacity units. The sensitivity of the device is so high that between the conditions «no smoke» and «light smoke» the deflection of the instrument is 50% of the scale length.

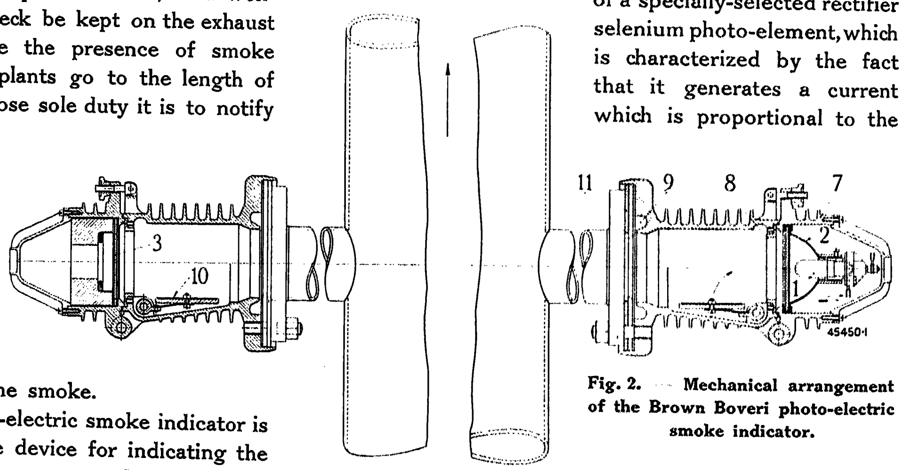


Fig. 2. — Mechanical arrangement of the Brown Boveri photo-electric smoke indicator.

An iron-wire resistance lamp 5, which, as is known, has the characteristic of maintaining a constant current for a wide variation of applied voltage, ensures a constant

intensity of the luminous source, independent of voltage fluctuations of the supply. In order to achieve a long life of the electric bulb, it is operated at only about half its nominal voltage. The adjustment of the device is effected by means of a variable resistance 6 in parallel with the lamp 1. This resistance enables not only small inevitable differences of the lamp characteristics on changing the bulb to be compensated, but also the desired illumination of the photo-cell for the «no smoke» condition to be accurately adjusted on site independently of the distance between the two organs, which varies from plant to plant. This method of regulation has the great advantage of not affecting the characteristic of the photo-cell by varying the resistance of its circuit, and therefore, ensures that the calibration of the indicating instrument is a permanent one. If desired, a recording instrument can, of course, be substituted for the indicating one.

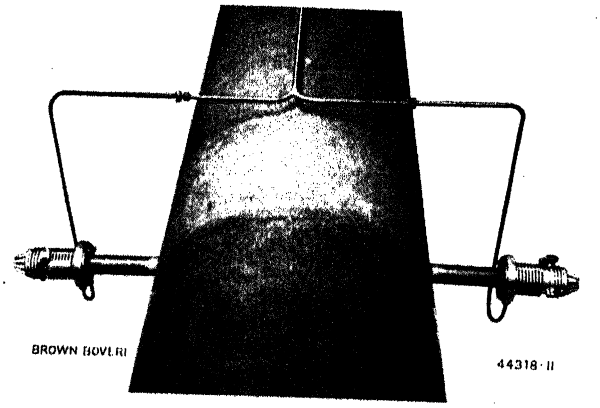


Fig. 3. — View showing the simple mounting of a Brown Boveri photo-electric smoke indicator on an exhaust duct.

Great care has been given to the mechanical design (Fig. 2) of the equipment. A special feature is the fact that all parts are at all times (also during service) accessible for inspections, cleaning, replacement of the bulb, etc. This has been made possible by mounting both the luminous source and the photo-cell in substantial hinged casings, provided with cooling fins and located outside the gas duct. The hinged part of the casing, containing either the lamp or the photo-cell, is sealed off from the smoke by means of the glass plate 8. Furthermore, air under slight pressure from any convenient source is supplied to the annular space 9 in the casing flange of the fixed part 11. A light scavenging action is effected thereby, ensuring freedom from smoke in the connecting arms.

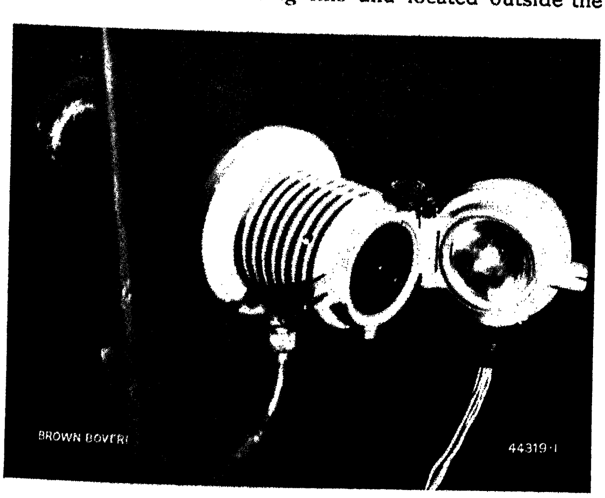


Fig. 4. — View of the apparatus open for inspection.

As already mentioned, all parts of the apparatus are continuously accessible. If, for instance, the glasses in front of the photo-cell or the lamp should become dirty through a failure of the scavenging air supply, they can easily be cleaned, in service. It is simply necessary to close the hinged door 10 first, whereupon the apparatus can be opened without smoke escaping from the chimney. Both photo-electric cell and luminous source are protected against undue heating by means of the cooling action of the casing fins and by the interposition of a heat insulating ring 11 between the mounting flange and the apparatus.

The device contains absolutely no delicate parts and is in every way suitable for the severe conditions existing in boiler houses. It is of unsurpassed reliability, for should even some unavoidable occurrence such as a break of a connection, a failure in the supply voltage to the lamp, or sooting up of the glasses due to failure of the scavenging air, take place, the meter immediately indicates «heavy smoke» and thereby draws the attention of the operating staff to the disturbance.

(MS 548) *H. Hvistendahl.*

Measurements carried out on the Brown Boveri electric boiler in the Zuckerfabrik & Raffinerie Aarberg (Switzerland).

Decimal index 621.181.646.0014.

WITH the desire to inform interested parties of the results of measurements carried out by some entirely neutral authority, on an electric boiler in service, Brown Boveri asked the Swiss Union of Boiler Proprietors to carry out measurements on the electric boiler placed in the sugar mill at Aarberg (Switzerland) with the object of determining the efficiency, the saturation of steam and the scope of regulation attainable. The far-seeing management of the sugar mill were good enough to turn over their boiler plant to the authority in question, to allow these tests to be made.

The boiler is built for the following conditions:—

Rated power input . .	6000 kW
Voltage	16,000 V (line voltage)
Current	three-phase A. C., 50 cycles
Steam pressure	18 kg/cm^2 gauge
Steam production . . .	abt. 9000 kg/h
Temperature of feed water	40—100° C.

The boiler is of standard Brown Boveri water-jet design, with automatic pressure and feed-water regulation.

The steam, chiefly generated from excess power, is used for heating and cooking exclusively. The feed-water supply is a mixture of condensate and of purified water from the lime-soda water-softening plant. It contains 40—70 mg/l of dissolved ammonia and about 20 mg/l of organic impurities. These impurities come from the calandria pans, the ammonia being a product of disinte-

gration from the albuminous substances contained in the beet. In cases of stoppages in the sugar mill, the boiler can be supplied with water taken from the neighbouring Aare River.

Fig. 1 shows the boiler with regulating apparatus and pumps. The same room contains the sheet-metal

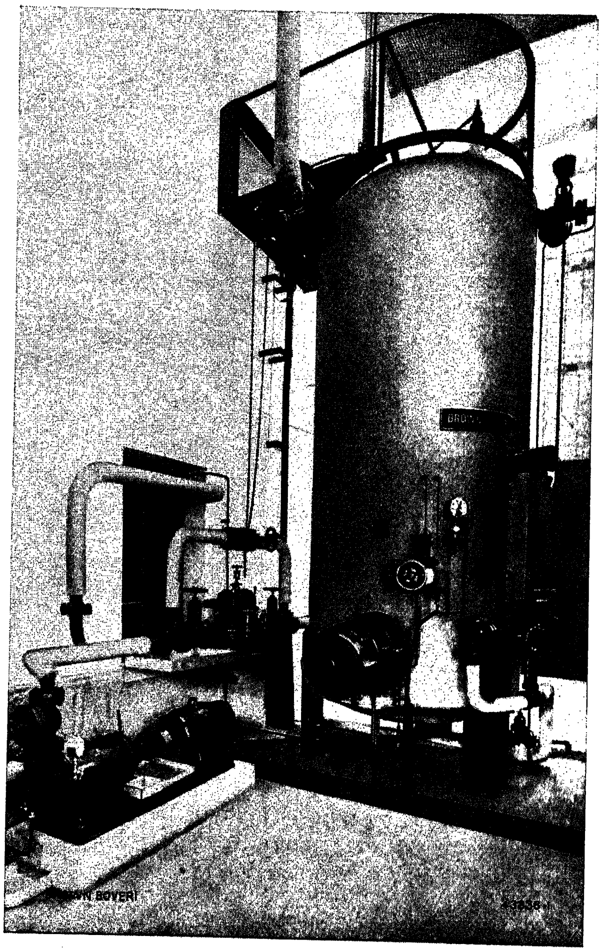


Fig. 1. — Zuckerfabrik & Raffinerie Aarberg, A.-G., Aarberg (Switzerland).

Electric boiler of 6000 kW input, 16,000 V, 19 kg/m² abs.

clad high-voltage framework and a low-voltage switchboard with precision measuring equipment, voltmeters and ammeters, a recording wattmeter, switch-boxes for the feed water and circulation pumps as well as signalling and safety devices. The auxiliary services are, also, connected up to the boiler leads through an auxiliary transformer mounted in the high-voltage framework, so that service can be kept up in cases of emergency, even if there are breakdowns on the electric distribution system of the sugar mill.

The electric boiler plant had consumed about 34 million kWh from the day it was started up, in October 1935 up to the day the measurements were carried out; this corresponds to about 50,000 t of steam generated without it having been necessary to change the electrodes.

The efficiency of the boiler was determined by measurement of the volume of feed water consumed, by means of a piston-type water meter of the Schmid design which was calibrated afterwards while, simultaneously, the power input was read off from calibrated panel-type precision meters, during tests extending over several hours. Temperatures and pressures were measured with calibrated thermometers and checking manometers. The saturation of the steam was ascertained by means of a specially-designed throttle-calorimeter, the use of which was suggested by the Swiss Union of Boiler Proprietors for the present tests; in this test the steam discharge was so adjusted that the velocity of the steam at the mouth of the discharge pipe corresponds to average velocity in the main steam duct. The tests to determine the steam saturation were especially carefully prepared and carried out with due regard to all secondary conditions. As is well known, very great errors can arise from the use of faulty testing equipment. A check carried out on the residue upon ignition of the boiler water and condensate (which, according to A. Kleinhans [1] can be taken as a measure when determining the saturation of the steam) showed very satisfactory conformity with the test results recorded. The full-load boiler efficiency including auxiliary drives but excluding feed water pump input was shown to be 98·53 %, and, at half-load, 97·48 %. The small water losses through the glands of the circulation pump as well as the small amount of water carried along with the steam are deducted from the volume of water supplied as being not vaporized. Thus, only the heat of the steam generated is calculated as useful heat. The measurements of steam saturation only showed 0·3 — 0·4 % of water in the steam generated, even with the highest possible alkaline contents of the boiler water, so that the steam can be termed very dry.

The tests on regulation carried out by the Association, after the other tests, showed that the Brown Boveri boiler is characterized by being able to work at any load desired between no load and full load and that the alkaline content of the boiler water does not affect the power input in the lower power range. It is also a factor of importance that the boiler can be run under relatively high salt concentration. The test report of the Association (SVDB) shows, further, that the boiler works entirely automatically and that all the supervision it requires is an intermittent checking of the conductivity of the boiler water.

(MS 547) *A. Strub. (Mo.)*

Calender drives by shunt commutator motors.

Decimal index 621. 34: 676. 2. 053. 4.

THE increasing demand by the newspaper printers for a quality of rotary-press paper with as uniform and as smooth a surface as possible has resulted in a major part of newsprint paper being subjected to a finishing smoothing process after its manufacture in the paper-making machine, a process which was, formerly, only reserved for paper for books or for illustrations. This is especially necessary in the case of newsprint paper in order to get good reproduction of illustrations. The great demand for calendered paper led to the increased manufacture of high-output calenders, which had to be equipped with modern variable-speed drives, in order to be fully utilized. In a few cases, it suffices to transform older available calenders by stepping up their working speed and by equipping them, to this end, with suitable driving equipment.

For smoothing and calendering, the paper is caused to pass between the rollers of the calender, under con-

[1] "Der Anteil verdampfter Salze am Dampfsalzgehalt", Archiv für Wärmewirtschaft und Dampfkesselwesen, No. 17, 1936, Vol. 51.

siderable pressure. According to the quality and thickness of the paper, this process can be carried out at different speeds, the speed chosen being the highest one allowable, this for economical reasons. Thus, the speed of the driving motors must be variable over a certain range and speed regulation must be smooth (without steps) over the said range. For threading in the paper between the rollers, when work on a new roll of paper is begun, the speed must be reduced to a low value and then, when threading in is accomplished, it must be increased as quickly as is possible, although this must be done smoothly and without jerks, until the highest figure compatible with the quality of the paper worked on is attained. Further, attendance must be made as simple as possible to allow the calender attendant to give his whole attention to the machine and to the run of the paper. These conditions can be fulfilled by a D. C. motor in Ward-Leonard or in booster connection or else by a shunt commutator motor with speed regulation without losses. To simplify operations, all such drives are equipped, to-day, with push-button control so that all switchings may be carried out by the calender attendant from his usual post, simply by depressing buttons.

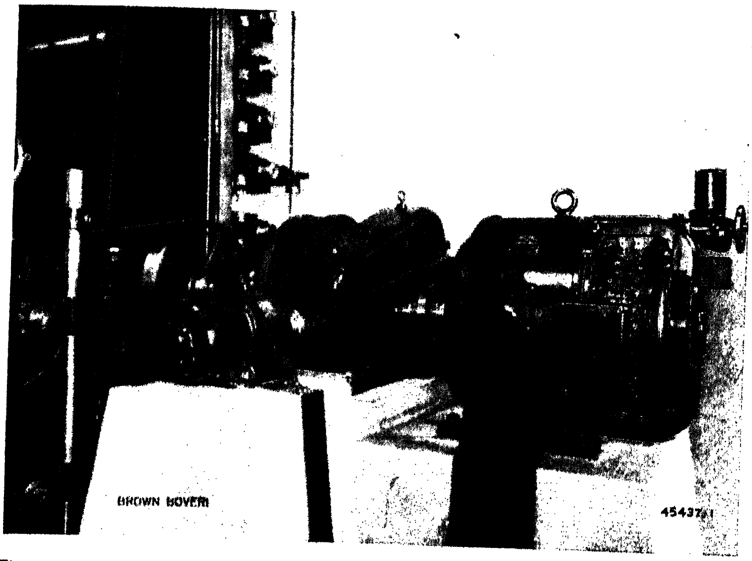


Fig. 1. Two-motor drive of a twelve-roller calender by means of a shunt commutator motor, 75 kW, as main motor.

Fig. 1 shows a calender of this kind with its electric drive, which was put up, last year, in the Papeteries de Jean d'Heures in Lisle-en-Rigault (France). As is customary in modern calenders, drive is through a reduction gear straight to a calender roller. For calendering proper, in the 60—180 m/min range, a shunt commutator motor of 75 kW is used, the speed of which can be varied over the said range by remote brush-rocker displacement. For the threading in speed of 10 m/min, a small auxiliary motor of 5 kW drives the pinion shaft of the main drive at the low speed required through a bevel gear and an overhauling clutch. Both main and auxiliary reduction gears with the overhauling clutch are in a common cast-iron housing, totally enclosed and thus form a pleasing whole, which takes up little space. This arrangement with a main and auxiliary motor is chiefly interesting because it allows of attaining a threading-in speed which is absolutely uniform and quite independent of variation of the torque. At the same time, the auxiliary motor can always generate the necessary torque for getting the calender going, under all circumstances; after a prolonged stoppage this torque may well exceed three times the rated working torque. These qualities make drive by two motors considerably superior to other drives which may appear simpler at first glance. The entire drive is controlled by push-buttons mounted in a main push-button box and allows of the five following switching operations:—

"Threading in", "Calendering", "Faster", "Slower", "Stop".

The transition from threading-in speed to the lowest working speed and the taking over of the load torque by the main motor takes place quite automatically and without jerks, thanks to the overhauling clutch, and this is a very important factor as it prevents stressing the paper in manufacture. As soon as the main motor has taken over the load, the coupling disengages automatically and the auxiliary motor is stopped. The working speed desired is adjusted to by displacement of the brush rocker of the commutator motor, by means of the push-buttons "faster" and "slower". In order to stop the calender and its drive, it suffices to depress the "stop" push-button.

A drive of this type with shunt commutator motor is suitable to all calenders of small and big output. As compared to the D. C. drive, still used, advantageously, for wide super-calenders of big output and high working speed, the fact that the shunt commutator motor is an economical current consumer which can be connected straight to the three-phase low-voltage distribution, should be stressed. Further, apart from very big drives, the space taken up is smaller because the converter set requisite to D. C. drive is done away with. A large number of these drives have been in service for years and have entirely fulfilled expectations, both technically and economically. The wide experience enjoyed by Brown Boveri in this field and resulting from the numerous calender drives they have put in, with outputs up to 375 kW, place them in a position to be able to advise as to the most advantageous layout for each particular case.

(MS 549) *E. Oschwald. (Mo.)*

The scavenging-blower plant on the motor ship "Saturnia".

Decimal index 621.436.058.2 : 629.123.23.

THE scavenging-blower plant of the Italian passenger motor liner "Saturnia" is remarkable as it comprises the biggest scavenging blowers yet built for direct-electric drive by D. C. turbo-motors. The ship was equipped recently (maiden trip 20th August, 1936) with a new main-engine plant, considerably more powerful than the former one and composed of two double-acting Sulzer two-cycle Diesel engines, built under licence agreement by the Cantieri Riuniti dell'Adriatico, Triest. The Diesel engines have a rated output of 2×14,000 H. P. at 130 r. p. m. Under test, a maximum output of 2×20,800 H. P. at about 152 r. p. m. was reached. With its main-engine plant of over 40,000 H. P. the "Saturnia" is the most powerful twin-shaft motor passenger vessel afloat (see frontispiece).

Scavenging air is delivered by three Brown Boveri turbo-blowers (two for standard service, one as a stand-by); each of these is designed for a delivery of 1800 m^3/min of air and a pressure difference of 1800 mm water gauge. This calls for a power input from the driving motor of about 700 kW, measured at the motor terminals, and it corresponds to 3180 A at 220 V. The rated speed of the motors is 2350 r. p. m., which can be regulated between 2000 and about 2500 r. p. m. These are exceptionally severe conditions for a D. C. motor and were most successfully met, thanks to the very wide experience Brown Boveri has gained in this special field of high-speed D. C. machinery.

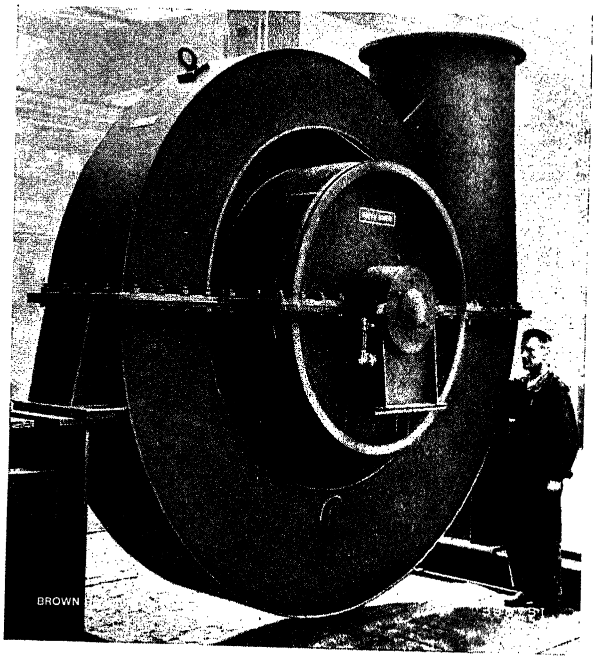


Fig. 1. — Welded spiral housing of a turbo-scavenging blower for M. S. "Saturnia".

The welded design used for the blower casings is worthy of note (Fig. 1). The impellers are of the well-known Brown Boveri design with blades having studs milled out of the solid blade itself which are, then, rivetted to the discs on either side (Fig. 2). This is done by passing the studs through holes drilled in the discs and then rivetting them tightly and countersunk to the said discs. In this way, no rivet heads protrude into the air channels, to obstruct the flow of air and be worn down, themselves. This is, certainly, a more expensive design than that occasionally encountered where blades are bent to a U or Z form, traversed by rivets with projecting heads. However, when the importance of the reliability of the scavenging blower is realized, it will be immediately understood, that only the best design is good enough. As a departure from the earlier bearing design, these blowers have automatically-lubricated roller bearings, which are being used, to-day, more and more extensively for this kind of machinery. The lubricating device is, thus, considerably simplified (elimination of oil pumps) and the length of the set is, also, reduced.

The D. C. turbo-motor is of enclosed-ventilated design with shunt-interpole-compound winding, the latter to prevent too great speed rise and harmful overloading. A compensating winding is not required on Brown Boveri high-speed D. C. motors.

There is an illustration of the complete blower set on page 108 of The Brown Boveri Review of the year 1936. Fig. 3 shows how the set is located on board the "Saturnia". It is remarkable to note that the axis of the sets are placed athwartship. This arrangement was used, earlier, for big Brown Boveri scavenging blowers and no disadvantages developed therefrom. As is usual, the blower is lodged in a suction chamber, the motor being outside and in an accessible position. The scavenging air is drawn in across the whole engine room and, thus, serves for ventilating, as well. There has been no annoyance occasioned by the noise of the blower running.

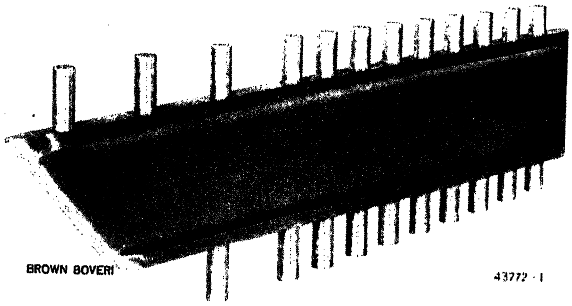


Fig. 2. — Blade of scavenging blower of Brown Boveri design with studs for rivetting, milled out of the solid blade.

In order to diminish the stress on the rivetted studs, the blades are made lighter by milling away material from them.

Since 1915/16, when Brown Boveri was the first firm to build scavenging turbo-blowers and up to the end of

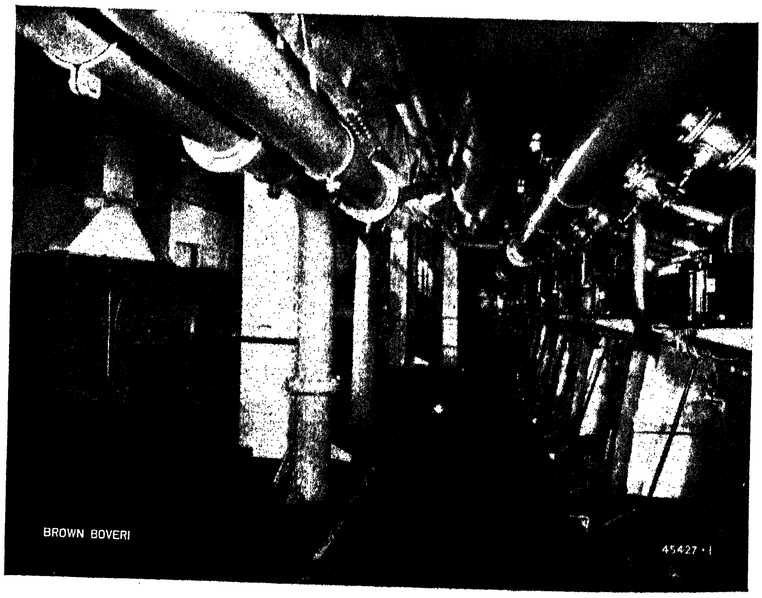


Fig. 3. — Scavenging-blow plant on board M. S. "Saturnia".

The blowers are in a suction chamber but their driving motors are outside in very accessible positions and are easy to supervise. The position of these high-speed sets, athwartship, will be noted.

1936, 265 scavenging-blower sets have been delivered, the total output of which attains about 190 000 m³/min with a corresponding power input of all the driving motors of 62,430 kW at motor terminals. The total volume of air corresponds to that required by a Diesel engine of about 1·4 million H. P. The average blower output is about 700 m³/min and the biggest output for one unit is 2750 m³/min; the highest scavenging pressure built to being 1·45 kg/cm² gauge.

It is a happy circumstance that Brown Boveri build both blowers and high-speed D. C. driving motors, which are not such a common feature. The fact that the firm has brought the latter to a high degree of perfection has, without a doubt, been a factor in bringing in many orders for this class of machinery.

(MS 539) *E. Klingelfuss. (Mo.)*

The electric drive of plate-working machines.

Decimal index 621.34 : 621.981.

GENERALLY speaking, the determining factor in the choice of the electric drive for machines used for plate working is the high frequency of operation which characterizes the said machines. This factor plays a part both in determining the driving motor and in choosing the control apparatus. It will be obvious that contactor control which simplifies and facilitates attendance is given preference, to-day, over the type of drive used formerly with manually-operated controller. Three typical cases of drives for plate-working machines are described briefly, here.

Fig. 1 shows a *plate-straightening machine* for which a reversible three-phase motor of 17 kW output and a frequency of operation of 300 per hour was required. The, relatively, big output and high starting torque, of about 150 % of the rated torque, were the reasons why a slip-ring motor was chosen for the drive.

The motor is coupled to the shaft of the machine and the contactor control is lodged in a small iron framework with sheet-metal housing, which is placed just behind the motor. The rotor resistance is placed above the cubicle and a part of this resistance is left inserted in circuit during service, in order to render operations more flexible and deaden surges— such as occur, for example, when the metal sheet is gripped by the machine, after the latter has been started up. There is a push-button box for the three impulses:— "Forward", "Reverse" and "Stop" placed on the machine itself. In order to facilitate the frequent reversing of the motor when it is running at full speed, the control gear is so designed that it is possible to switch over to reverse running without depressing the "Stop" push-button. This makes attendance very simple indeed and switching faults are eliminated.

A *plate-bending machine,* having similarly severe service conditions to meet, is shown in Fig. 2. It is driven by two motors. For the main drive, i. e. the reversible drive of the work roller, an 11-kW motor was asked for with a frequency of operation of 200 per hour, alternatively in one sense or the other. The second motor is not seen in the illustration, it is used to displace the roller so that the bend of the plate worked on may be adjusted to.

It is interesting that, despite the frequency of operation of the main drive, it was found possible to put in a squirrel cage motor. This simplifies the control still further. Behind the motor circuit breaker, which is always closed in service, there are, simply, two contactors. In this case, as well, the motor can be reversed, from full speed forward, by depressing the other push-button. Thanks to the very strong motor having a multiple deep

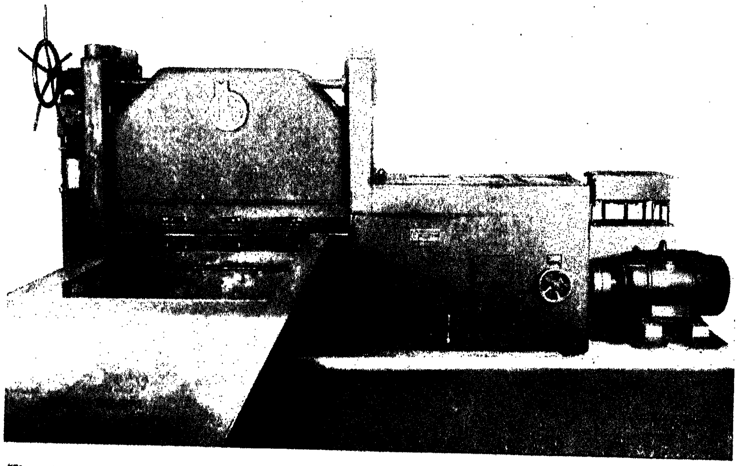


Fig. 1. — Plate-straightening machine with reversible drive by three-phase, slip-ring motor and contactor control.

Fig. 2. — Plate-bending machine with main drive by a 10.5-kW squirrel-cage motor and contactor control.

(Protective sheet-metal cover, removed.)

slot rotor, this kind of service can be carried out without any disadvantage, whatsoever.

For the motor for roller displacement designed for 3·7 kW with short switching-in time, practically the same

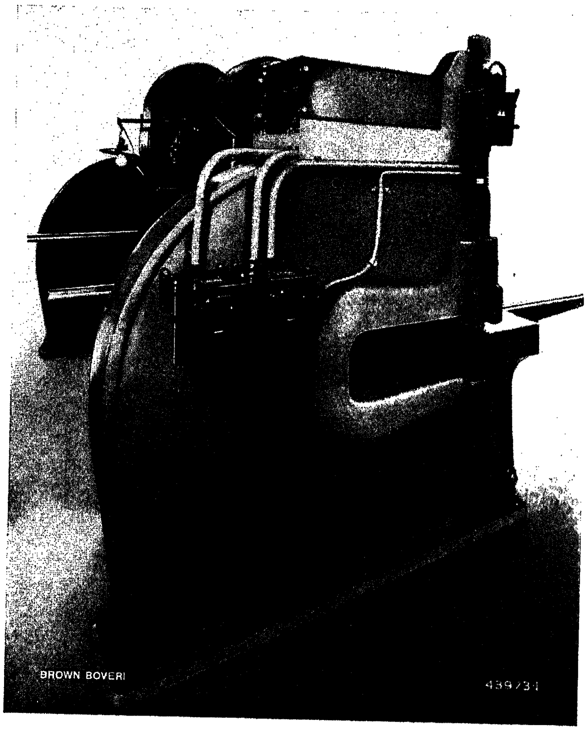


Fig. 3. — Shears with built-on three-phase flange motor of slip-ring type and contactor control built on to the machine.

apparatus is used namely:— a contactor switch and two control contactors. The attendance alone is somewhat different, the motor only running for as long as the push-button "In" or "Off" is depressed; therefore no separate "Stop" push-button is needed.

A still simpler design of control was that designed for the drive of a *shears*, shown in Fig. 3. The machine is driven by a three-phase flange motor of the slip-ring type, of 10·5-kW output which always runs in the same sense. An oil-immersed contactor is used for the stator circuit and one for the rotor circuit; both are built on to the machine. The rotor resistance is placed immediately above them.

There is a push-button box with three push buttons on the front of the machine. The stator contactor is closed by the "Start" push-button, which starts up the motor to a low speed, all the rotor resistance being inserted. As soon as it is desired to go over to full working speed, the "Work" push-button is depressed which switches in the rotor contactor and short-circuits most of the rotor resistance. The remainder of the resistance remains inserted, here, as was done for the plate-straightening machine described, in order to deaden shocks. The machine is stopped by means of the "Stop" push-button which cuts out both contactors.

The three examples given here show that modern drives of machine tools for plates can be formed of simple apparatus and be made so easy to handle that the high frequency of operation does not cause any trouble to the operator.

(*MS 552)* *S. Hopferwieser. (Mo.)*

Service reliability of Brown Boveri material.

Decimal index 6 (009.2): 621. 34.

As far back as 30 years ago, Brown Boveri took out the first patent on a spinning regulator and brought out the variable-speed A. C. commutator motors to drive ring spinning frames and doubling frames, at variable spinning speeds.

One of the first firms to make use of the advantages of this new driving method was the Textil A.-G. formerly J. Paravicini, in Landeck (Tyrol). When, in 1906—1907, this firm enlarged their cotton-spinning mill, which had been put up in 1901 and 1904, the ring spinning frames and doubling frames which it contained were equipped with A. C. commutator-motor drive (Fig. 1). In all, 58 variable-speed drives each of 6 kW, 400 V, 40 cycles were put in, of which 36 for ring spinning frames with a speed range of 600—880 r. p. m. and 22 for doubling frames with a speed range of 900—1200 and 700—950 r. p. m.

Fig. 1. — Textil A.-G., formerly J. Paravicini, Landeck (Tyrol).
Ring spinning frames with variable-speed individual drive by A. C. commutator motors, delivered in the years 1906—1907.

The motors are still in excellent condition, to-day, and run perfectly, which is worthy of note as this mill runs from time to time with several shifts per day.

(MS 521) *Prop.*

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THE BROWN BOVERI REVIEW

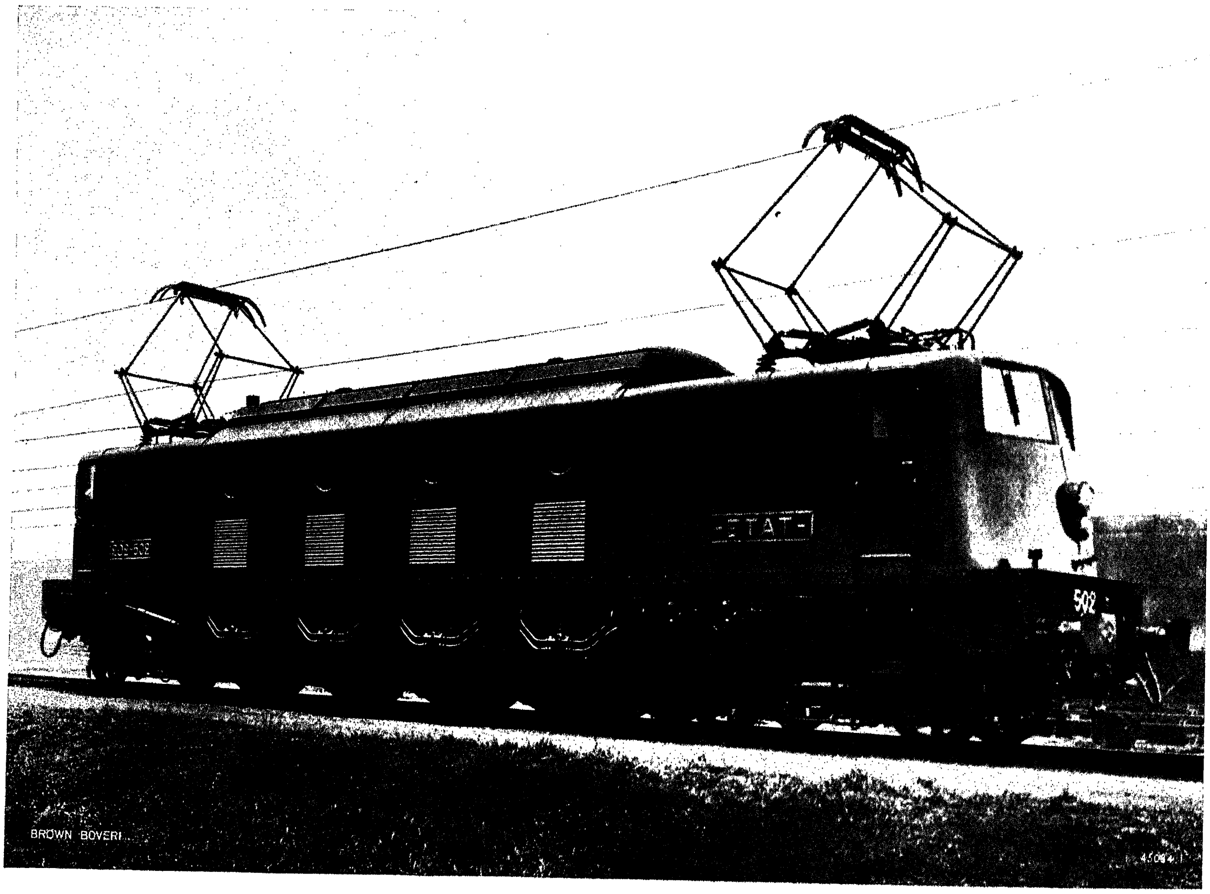
EDITED BY BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

THE WARFIELD MUTATOR PLANT OF THE CONSOLIDATED MINING AND SMELTING COMPANY OF CANADA (BRITISH COLUMBIA). WITH A TOTAL OUTPUT OF 36,700 kW.

CONTENTS:

Printed in Switzerland.

Brown Boveri
heavy full-gauge locomotives



2-Do-2 express-train locomotive, No. 502, of the French State Railways (Etat) for D. C. current at 1500 V, 4200 H.P., 69·5 km/h (one-hour rating), 130 km/h (exceptionally 150 km/h) maximum speed.
Built by the Cie. Electro-Mécanique, Paris, in collaboration with the Cie. de Fives-Lille.

Brown Boveri individual axle drive

on

68 locomotives

of this design with a total of

285,600 H.P. one-hour rating, in France alone

in service and building

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIV JULY, 1937 No. 7

INCREASING THE POWER OF DIESEL ENGINES AND AEROPLANE ENGINES BY THE BÜCHI PROCESS USING EXHAUST-GAS TURBO SUPERCHARGING. POSSIBILITY OF APPLYING EXHAUST-GAS TURBO SUPERCHARGING TO OTHER PURPOSES.

Decimal index 621. 436. 068. 2.

SUPERCHARGING for raising the power of Diesel engines is, nowadays, being used to an increasing extent by progressive Diesel-engine manufacturers all over the world, particularly with *4-stroke Diesels* which, due to their working process, are inherently at a disadvantage compared with the 2-stroke engines as regards power for a given size of engine. It might almost be said that the only hope of survival for the 4-stroke engine of big output is in the application of supercharging. In the case of high-speed engines, the 4-stroke high-powered engine with exhaust-gas turbo supercharging, today, shows even a certain superiority to the 2-stroke machine.

Various supercharging systems have been developed in the course of years. The oldest system, however, viz. the Büchi system with Brown Boveri exhaust-gas turbine-driven blowers, has achieved the greatest success, particularly where a power increase of more than, say 30 %, is required. The schemes to be discussed in this article are, therefore, essentially limited to 4-stroke Diesel engines with Büchi supercharging, in connection with which the following points will be briefly discussed.

I. The principle of supercharging, in particular with exhaust-gas turbine-driven blower, and the effect of supercharging on the Diesel engine.

II. The principle of the Büchi process.

III. The design of the supercharging unit and its assembly with the Diesel engine.

IV. Test results on four-stroke Diesel engines with Büchi supercharging.

V. Two-stroke Diesel engines and exhaust-gas turbo supercharging.

VI. The supercharging of aeroplane engines.

VII. Further possibilities of the application of exhaust-gas turbo supercharging as a means of increasing power (boiler combustion, heat-exchanging processes, chemical industry).

I. THE PRINCIPLE OF SUPERCHARGING, IN PARTICULAR WITH EXHAUST-GAS TURBINE-DRIVEN BLOWER, AND THE EFFECT OF SUPERCHARGING ON THE DIESEL ENGINE.

The standard 4-stroke Diesel engine, as is well-known, draws in its combustion air over a part of its working cycle, i. e. during the suction stroke, from the surrounding atmosphere. In this process, however, the available weight of air for combustion at the end of the suction stroke is not equal to the content of the cylinder multiplied by the specific weight of atmospheric air, but is reduced by:—

1. The residual exhaust gas which remains over in the compression space from the previous working cycle and which now mixes with the newly drawn-in air.
2. The increase in temperature of the air drawn in, due to its mixing with the residual exhaust gas and to its receiving heat from the hot parts of the compression space.
3. The throttling and frictional resistance of the inlet valves and passages. Under certain conditions, e. g. with high-speed engines, this reduction in pressure can be quite considerable.

If, now, on the other hand, the Diesel engine is supplied with precompressed and, if possible, cooled air, then a greater weight of air for combustion is available in the cylinder. But not only this, since the air enters the cylinder at a pressure above atmospheric, then it can be taken that the compression space will be scavenged of the residual gases to a great extent. This scavenging can be carried out much more effectively with the 4-stroke engine, as, in opposition to the 2-stroke engine, only the small flat compression space has to be scavenged and not the whole of the cylinder. Supercharging, therefore, has the following effects:—

(a) *Increase* in weight of air available for *combustion.*

(b) *Scavenging* of the residual gases.

(c) *Cooling* of all parts of the combustion chamber.

The greater air weight enables a greater quantity of fuel to be burnt and, hence, gives an increase in power which is obtained without increasing the temperatures and, consequently, the heat stresses. Tests[1] clearly show that the heat stresses are rather less and that only after an increase in power of about 50—70 % does the same heat-flow through the walls occur as with the unsupercharged engine. The maximum temperature of combustion is, of course, determined by the excess air only. If the same excess air is used as with the unsupercharged engine then the maximum temperature obtained will also be the same. With the supercharged engine, however, it is possible to work with any desired air excess and so to control the temperatures. It has been shown that the scavenging has an extremely important influence on the degree of power increase obtained, so that it is a very essential consideration in connection with the supercharging of 4-stroke Diesels. The essential feature of the Büchi process is, as we shall see, that it enables particularly effective scavenging to be carried out by producing violent pressure fluctuations before the exhaust-gas turbine, by means of suitable subdivision of the exhaust-gas piping, special adjustments to the valve gear, etc.

However, not only the heat stresses, but also the mechanical stresses in the crank shaft, connecting rods and bearings can be kept within normal limits, as, by controlling the fuel supply to the Diesel engine, an unpermissible increase of the maximum pressure with supercharged operation can be avoided. Essentially, the indicator diagram of the supercharged Diesel engine differs in actual practice from that of a normal Diesel only through its greater width.[2]

It is perhaps advisable, here, to point out that the word "supercharging" and the conception "power increase" are not to be confused with the idea of "overload". As stated, operation with supercharging is, on the other hand, to be considered as a quite normal continuous operation condition. If with a supercharged engine at 60 % additional load, the same exhaust-gas temperature leaving the exhaust valves and cooling water outlet temperatures occur as with an unsupercharged engine, then the heat stresses in the two machines can be taken to be equal. It follows, however, from this that the supercharged engine can also carry an overload, in the case of exhaust gas turbo charging even to a much greater extent than the unsupercharged engine, since, as will be shown, with exhaust-gas turbo charging, as against other processes, the air supply increases necessarily with increasing load.

The precompression of the air for combustion naturally requires a certain expenditure of energy which increases with increasing amount of precompression and hence increase of power. In order that the supercharging may be effected economically, all external energy consumption even in the form of increased fuel consumption per B. H. P. hour must be avoided. In the case of Büchi supercharging this follows due to the driving of the centrifugal compressor through an exhaust gas turbine which is itself driven from the exhaust gases of the Diesel engine. In other words, the energy consumption for the precompression of the air is obtained from the working process of the Diesel engine itself.[1]

If we consider the indicator diagram of a 4-stroke engine, it is clear that the expansion of the gas in the Diesel cylinder is not complete. When the exhaust valve opens, the gases still have a considerable excess pressure and a large amount of heat energy. In the exhaust-gas turbine the expansion is now carried

[1] Pflaum: "Interaction of engine and blower with supercharged Diesel engines". Proceedings of the 74th General Meeting of the V. D. I. Darmstadt 1936.

Stodola: "Power tests on a Diesel engine with Büchi supercharging" Z. VDI No. 13/1928, page 421.

[2] In the case of Diesel engines with air injection of the fuel (in modern practice only seldom used), too great increase of the combustion pressure in charging operation was avoided by enlarging the compression space, this on account of the air-injecting compressor, that is to say, to allow of retaining the usual air injection pressures. Modern Diesel engines work with mechanical fuel injection and are designed, from the beginning, for higher ignition pressures than the earlier air-injection machines. With supercharged operation, the pressure increase due to combustion can be adjusted by means of delayed injection, so that, even without altering the combustion space, the pressure remains within admissible limits.

[1] Apart from the desire to find a new field of application for the centrifugal blower, Brown Boveri conceived the idea in 1923 of doing all in their power to develop exhaust-gas turbo supercharging of Diesel engines in order to assist the development of the gas turbine, and to collect operating experience with it. As is well known, with the gas turbine proper, very high gas temperatures occur which present almost insuperable difficulties. If now the gases are cooled, by making them do useful work in the Diesel engine which serves primarily as a combustion chamber, to such a temperature as is permissible for the gas turbine blading, i. e. at present about 600 °C, it would be possible to discharge the gases direct to a turbine with uncooled blades. If, with time, due to metallurgical developments, higher temperatures become possible then the work diagram of the Diesel engine can be cut down and the exhaust gas turbine made to develop more power. The gas turbine, in addition to the Diesel engine, would then develop a part of the main output, i. e. the unit would become a combined Diesel turbine combustion engine as originally proposed (1905) by Mr. Büchi. Admittedly, up to the present, the development has proceeded otherwise. Today, the exhaust gas turbine simply drives the supercharging blower and all improvements have, so far, been used rather in the direction of reducing the exhaust-gas pressure entering the turbine whilst maintaining the supercharging pressure as high as possible.

down to atmospheric pressure, and hence the exhaust energy which would otherwise be lost is made use of. In this case also, as in the case of exhaust-steam turbines arranged in series with reciprocating steam engines, an exhaust-gas turbine is employed to make use of the last portion of the expansion of the gases which otherwise would be thrown away. It can, therefore, now be said that the time when incomplete expansion with reciprocating engines could not be avoided, is past.

Fig. 1 shows the fundamental arrangement of a Diesel engine and exhaust-gas turbo blower, for simplicity only one cylinder being shown. The blower and gas turbine are combined into a single unit on one shaft: the supercharging unit. *There is no external auxiliary motor or automatic control.* The supercharging unit is, solely, connected thermally to the Diesel engine. The diagram shows the piston at the upper dead centre, i. e. in the position where the gases have been discharged to the turbine. Both the exhaust and air-inlet valves are open at this point. Precompressed air enters from the blower and scavenges the compression space. Immediately afterwards the piston starts to move downwards when, it may be mentioned, the precompressed air does work. The exhaust valve then closes and the whole cylinder is charged with precompressed clean air.

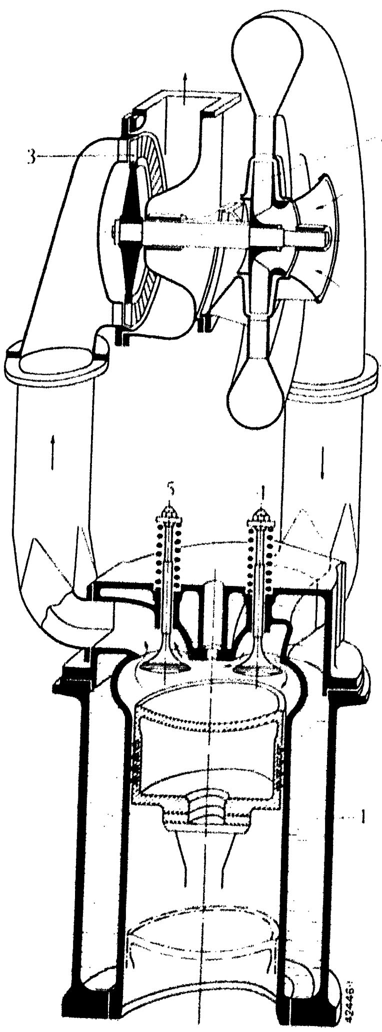


Fig. 1. — Diagram of exhaust-gas turbo supercharged 4-stroke Diesel.

1. Diesel cylinder.
2. Supercharging blower.
3. Exhaust-gas turbine.
4. Air inlet valve.
5. Exhaust valve.

The piston is at the top dead centre and the exhaust gases have, therefore, just been discharged. The inlet and exhaust valves are open so that the compression space is well scavenged of the residual gases and the cylinder cover, piston top and exhaust valve are cooled by the incoming supercharged air.

The charging unit with exhaust-gas turbine drive adapts itself automatically to all loads, e. g. with increasing load more fuel is injected, hence more exhaust gases are available (momentarily also at somewhat higher temperature), the exhaust-gas turbine gives more power to drive the blower, which delivers a greater volume of air at higher pressure. To each load there is a corresponding quite definite speed of the charging unit, to which the unit sets itself automatically at each change in load. The charging unit has shown itself in this way to be a very sensitive load indicator. The load on the engine can be determined at any time from the speed or the air pressure of the charging unit. If, on the other hand, in operation, the speed of the charging unit for a given load varies from the known normal value, this can be taken to indicate some fault, e.g. in the combustion.

Although the construction of the charging unit and its operation in conjunction with the Diesel engine appears so simple, it is, however, very difficult to obtain the right dimensions of the operating parts, i. e. the turbine nozzles with the turbine wheel and the blower impeller with the diffuser. The operating condition of the charging unit, for instance, depends not only on the pressure volume curve of the blower but also on the air-absorbing capacity and the resistance curve of the Diesel engine[1], that is, the curve which shows for each air volume what pressure is necessary to deliver this air quantity through the inlet valve into the combustion chamber, to scavenge the exhaust gases through the exhaust valve and to deliver the mixture of scavenge air and exhaust gases to the atmosphere. A part of this resistance occurs through the turbine nozzles themselves which place a resistance in the way of the exhaust gases entering the turbine. As is well known, the intersecting point of this resistance curve with the particular p_v curve of the blower gives the operating point of the blower and it is necessary, to obtain good results from the supercharging, for the normal operating point to be in the region of best efficiency of the blower. In the case of *supercharging without an auxiliary motor* for the gas turbine it is very important, indeed, to consider each percent in efficiency of the blower and turbine.

The actual power of the gas turbine is given by

$$L_T = \eta_T \cdot G_2 \cdot c_{p_G} \frac{(T_2' - T_1')}{A}$$

where

η_T = Turbine adiabatic efficiency.
G_2 = Gas weight per second.

[1] See also Schmitt "Operation of centrifugal blower and gas turbine in conjunction with supercharged Diesel engines". Z. VDI 1937, page 28.

c_{p_G} = Specific heat of the exhaust gases at constant pressure $\cong 0{\cdot}265$.
T_2' = Temperature entering gas turbine.
T_1' = Temperature leaving gas turbine (with adiabatic expansion).

The maximum power obtainable from the gas turbine is, therefore, limited by the maximum temperature (T_2') entering the turbine, which, in present-day practice, is about 600° C.

On the other hand the adiabatic work of compression necessary is

$$L_G = \frac{1}{\eta_G} \cdot G_1 \cdot c_{p_L} \cdot \frac{(T_2 - T_1)}{A}$$

T_2 is obtained from the required compression of the air from state p_1, T_1 to the pressure p_2 from the formula

$$T_2 = T_1 \left(\frac{p_2}{p_1}\right)^{\frac{\varkappa-1}{\varkappa}}$$

η_G = Adiabatic efficiency of blower.
G_1 = Weight of air per second.
c_{p_L} = Specific heat of air at constant pressure $\cong 0{\cdot}242$.
T_2 = Air temperature leaving blower (with adiabatic compression).
T_1 = Air temperature entering blower.
p_2 = Blower discharge pressure.
p_1 = Blower suction pressure.
$\varkappa$ = Exponent of compression curve = $1{\cdot}4$.

The highest possible supercharging pressure p_2 should be created with the gas turbine work available in order to force into the cylinder the greatest possible weight of air and to have a sufficient pressure drop available for scavenging, which is so important. Hence, for a gas turbine unit if the mechanical efficiency of the supercharging unit is signified by η_m, then

$$\eta_m \cdot L_T = L_G$$

i. e. the useful work supplied by the turbine is at each instant equal to the work of compression absorbed by the blower

$$\eta_m \cdot \eta_T \cdot G_2 \cdot c_{p_G} \frac{(T_2' - T_1')}{A} = \frac{1}{\eta_G} \cdot G_1 \cdot c_{p_L} \frac{(T_2 - T_1)}{A}$$

We can substitute $k \cdot G_1$ for G_2 where k is approximately $1{\cdot}025$. The overall efficiency of the supercharging unit is

$$\eta_{tot} = \eta_m \cdot \eta_T \cdot \eta_G$$

therefore, with the values for c_p as mentioned above:—

$$\eta_{tot} = 0{\cdot}89 \frac{(T_2 - T_1)}{(T_2' - T_1')}$$

It can easily be seen that the higher the overall efficiency of the supercharging unit is the higher will be the supercharging pressure generated. There is a lower limit below which it is not permissible to let the supercharging pressure fall, as, otherwise, a sufficient increase in power would not be possible without increasing the heat stresses. On the other hand it is necessary to avoid having to supply an auxiliary motor for this supercharging unit. It is, therefore, essential that all steps are taken to ensure that the *overall efficiency of the supercharging unit is a maximum.* Generally speaking, the overall efficiency with Brown Boveri supercharging units has an average value of 50—60 %, with the smallest units it may drop to about 40 %, on the other hand with the larger supercharging units (Fig. 29) over 70 % overall efficiency has already been obtained.

The thermo-dynamics of the supercharging unit in combination with the Diesel engine[1] is, therefore, not a very simple business. Fortunately, however, if once the best conditions for the blower and gas turbine at the normal operating point have been fixed for a given type of Diesel engine, then, due to the favourable shape of the resistance curve of the Diesel, the unit will operate in the region of the best possible efficiency at all other loads also.

II. THE PRINCIPLE OF THE BÜCHI PROCESS.

Every cylinder of a multi-cylinder Diesel engine does not have its own charging unit but, as a rule, a single gas turbine-driven blower is provided for all the cylinders (Fig. 2). In order to obtain the above-mentioned scavenging (which is so important for obtaining an increase in power) without excessive air pressure, Büchi suggested the artificial creation of big "static" determined pressure fluctuations in the exhaust pipe between engine and exhaust-gas turbine. In multi-cylinder engines, this means a subdivision of the exhaust-gas piping so that only such cylinders discharge into a common exhaust pipe as will not mutually interfere with the scavenging process. The subdivision must be carried out up to just in front of the nozzles of the exhaust-gas turbine. In place of the said subdivision, several exhaust-gas turbines, separate from one another, could be used, for the same Diesel engine. It has been found that to give effective scavenging there must be an interval between successive exhausts of abt. 180°, i. e. at the most four cylinders of a four-stroke cycle engine firing consecutively can be connected to a common exhaust pipe. In this way pressure waves occur in the exhaust pipe, the scavenging process taking place during the periods of minimum pressure in these waves. These pressure waves give rise to considerable pressure surges at the beginning of the exhaust stroke, before the exhaust-gas turbine, the output of which, is increased,

[1] For detailed investigations of this question see foot note to page 176.

thereby. On the other hand, they also cause big pressure drops during the period of scavenging which produce an efficient scavenging effect. Fig. 2 shows the pressure waves in the case of a 6-cylinder engine with three cylinders discharging into each of

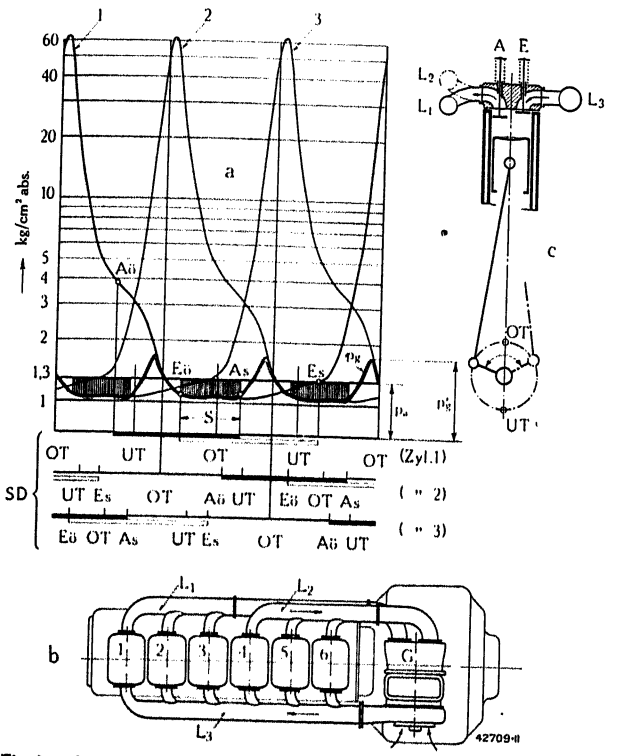


Fig. 2. — Supercharging of 4-stroke Diesel engine by the Büchi system. (a) Pressure variations in the exhaust manifold with 3 Diesel cylinders per pipe.

Ordinates: Pressure in kg/cm² abs (logarithmic scale).
Abscissae: Crank angle over 2 revolutions 4 strokes.

1. Pressure variation in cylinder 1.
2. " " " " 2.
3. " " " " 3.

SD. Valve timing for Diesel cylinders Nos. 1 to 3.
OT. Top-dead centre.
UT. Bottom-dead centre.
Eö. Air inlet valve opens.
Aö. Exhaust valve opens.
As. Exhaust valve closes.
Es. Air inlet valve closes.
S. Scavenging period.
p_a. Supercharged air pressure.
p_g'. Maximum pressure of exhaust gases in exhaust manifold.
Black bar: exhaust valve open.
White bar: air inlet valve open.

(b) Diagram of a 6-cylinder, 4-stroke Diesel engine.

L_1. Exhaust manifold for cylinders 1–3.
L_2. Exhaust manifold for cylinders 4–6.
L_3. Supercharged air piping.
G. Supercharging blower unit.

(c) Section through a Diesel engine cylinder.

A. Exhaust valve.
E. Air inlet valve.
L_1, L_2, L_3, OT, UT: as for (a) and (b).

two exhaust pipes. The lines 1, 2, 3 show the pressure variation (ordinates plotted logarithmically) in cylinders 1, 2, 3, on the assumption that the exhaust from each is not interfered with by the others. Since, however, the three cylinders discharge into a common manifold, there is created in this manifold, as shown, due to overlapping of the three exhaust impulses, a resultant pressure wave with troughs and pressure peaks. p_a is the pressure of the precompressed air, S is the scavenging period, during which the exhaust valve and the air inlet valve of cylinder 1 are open together. As will be seen, during this period, the exhaust gas pressure is considerably below the pressure of the charging air and there exists a definite pressure drop between the air inlet and exhaust piping

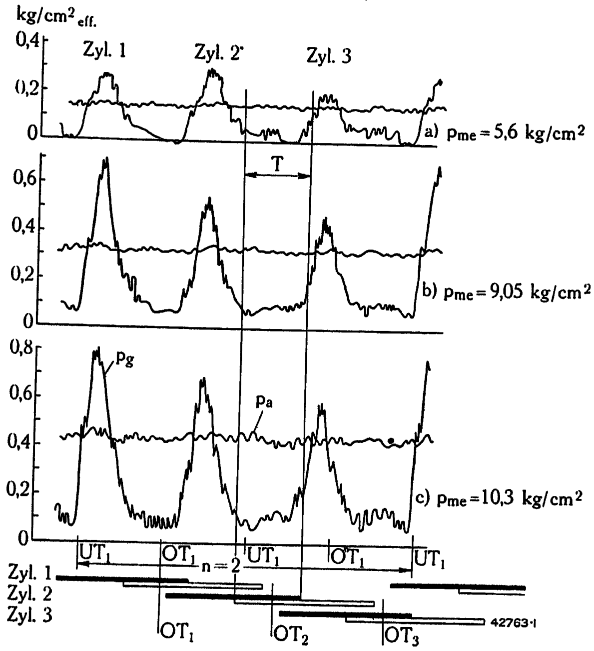


Fig. 3. — Variation of supercharging and exhaust-gas pressure at various loads on a 6-cylinder MAN 4-stroke Diesel engine running at 700 r.p.m.

(From Pflaum, see footnote 1.)

One exhaust manifold each for cylinders 1—3 and 4—6.

Black bar: exhaust valve open.
White bar: air inlet valve open.

which results in a powerful current of scavenging air flowing between them. Just before the exhaust valve of cylinder 1 closes (point A_s) the exhaust valve of cylinder 2 opens (point $A_ö$ cylinder 2) and the new rush of exhaust gas causes a momentary pressure increase above the charging pressure at the peak p_g'. Since at this instant the valves of cylinders 1 and 3 are closed, there is no backward flow of gas into the other cylinders. The process is then repeated for cylinders 2 and 3.

Fig. 3[1] shows the actual shape of the pressure waves in practice. The curves have been taken from a 6-cylinder MAN Diesel engine with Büchi supercharging, Type W 6 Vu 30/38, at a speed of 700 r.p.m. and at various loads (M.E.P. = 5·6, 9·05 and 10·3 kg/cm²). The higher the efficiency of the charging unit, the higher the charging pressure, hence,

[1] From Pflaum: "Interaction of engine and blower with supercharged Diesel engines". Proceedings of the 74th General Meeting of the V.D.I., Darmstadt, 1936.

the broader and deeper are the scavenging troughs. Fig. 3 also shows the importance of the timing of the scavenging periods between the exhaust impulses. This timing is obtained by a special adjustment of the valve drive which is a further feature of the Büchi process. The formation of the pressure waves is, further, caused by special dimensioning of the cross-sectional area and volume of the exhaust piping as well as the nozzle area of the gas turbine.

In opposition to recently suggested systems, which have, however, been put forward before (Petters, England, Westinghouse, U. S. A., Wibu System, Poland) which make use of the resonating oscillations of exhaust gas in a pipe of a definite length in order to draw the scavenging air through the Diesel cylinder during the period of under-pressure, the pressure waves in the Büchi process are "quasi-static" oscillations which occur at the same crank angles for all loads and speeds. The above-mentioned systems with "harmonic" oscillations are, on the other hand, dependent on the speed of the engine, in other words, the length of the exhaust piping is only suitable for a definite speed. The systems using resonating oscillations are, therefore, theoretically very interesting, but cannot be carried out in practice.

III. THE DESIGN OF THE SUPERCHARGING UNIT AND ITS ASSEMBLY WITH THE DIESEL ENGINE.

Fig. 4 shows the essential parts of a supercharging unit, i. e. the nozzle ring with the gas-turbine wheel and the blower impeller with the diffuser.

The common shaft for the gas turbine and blower runs in two ball or roller bearings arranged at the ends and readily accessible. The bearings are usually oil-lubricated, but in special cases, with grease. In the case of oil lubrication, each bearing has generally, its own screw oil pump. Only for the smaller types and, in special cases, for larger types, is the lubricating oil of the Diesel engine also used for the bearings of the supercharging unit.

The nozzles are of heat-resisting steel plate cast into a cast-iron ring. The turbine is of the impulse type. The impulse principle must be used in this case due to the partial admission and the fluctuation in flow of the gases.[1]

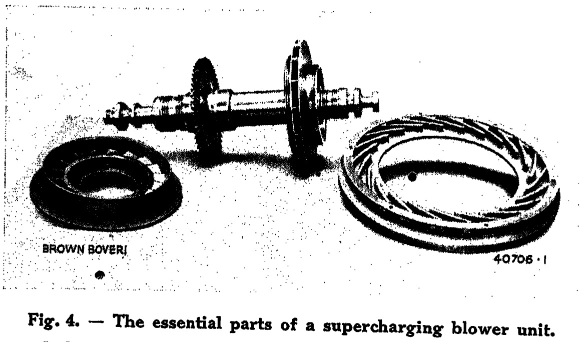


Fig. 4. — The essential parts of a supercharging blower unit.
Left:— Nozzle ring and impulse wheel of the gas turbine.
Right:— Impeller and diffuser of the supercharging blower.
The common shaft is supported in two ball or roller bearings.

The question is often raised whether the Büchi system of combining groups of cylinders to several exhaust manifolds and the leading of these separately to the nozzle ring is not rather involved and whether the scavenging could not be still more effectively obtained if each cylinder were arranged with its own exhaust pipe leading to a separate nozzle group. This would lead, however, to a nozzle ring of impracticably large diameter. With the Büchi system the same nozzle surface is used consecutively by three or four cylinders. With separate nozzle groups for each individual cylinder, the nozzle ring would be three or four times greater in circumference. The dimensions of the turbine impulse wheel would be such as to lead to difficulty in design, due to the high temperatures and, finally, the arrangement of so many individual exhaust pipes and, above all, their connection to a single turbine would be, practically, impossible. A more feasible solution would be to have several supercharging units for each Diesel engine, in the extreme case, for instance, one for each cylinder. It is a well known fact, however, that with decreasing size the efficiency of the turbine and the blower rapidly decreases and since the application of exhaust-gas turbo supercharging is only possible above a certain minimum efficiency of turbine and blower, this method is also not feasible. In practice, it would be a step in the wrong direction to use, instead of one supercharging unit with high efficiency, a number of smaller units with poor efficiencies, thereby reducing the performance of supercharging sensibly. The solution offered by the Büchi system gives, in fact, the most favourable conditions in every respect.

The turbine wheel is made of high-quality heat-resisting steel. With the smaller units, it is made in one with the shaft, whilst with the larger sizes it is forged as a solid disc and attached to the shaft on both sides.

The blades are milled from the solid bar also of heat resisting steel and are of a special form to give a very high efficiency. The high quality of the blade material and the complexities of manufacture involving numerous milling operations make the blades relatively the most expensive part of the whole unit. In most cases the blades are attached to the wheel disc by the design originally put forward by Laval, which is particularly suitable for high peripheral velocities. The blade roots are passed sideways through the wheel rim which is milled with slots to suit. The

[1] On the other hand, the gas turbine for the charging unit of the Velox steam generator is a simple multi-stage reaction turbine, since, in this case, the turbine operates in a continuous gas stream.

resulting projections of the blade root on each side are rivetted. The blade roots at the wheel rim abut closely to form a continuous surface. The blades are sharpened at the tip in the normal way so that no harm will result from a possible occasional rubbing.

The blower impeller is mounted on the shaft in the normal way and secured with a key and shaft nut. The well known Brown Boveri construction with rivetted blades is used for the impeller: the rivets which connect the blades to the two impeller discs are milled from the solid blade material. They are forced through the side discs which are drilled to gauge and are rivetted from the outside with smooth countersunk heads. With this construction there are no rivet heads projecting into the air passages which would not only disturb the flow but would also lead to erosion and corrosion. For these high-quality blowers, only the most perfect construction is sufficient.

In order to give a high efficiency the blower diffuser is bladed. As a general rule it is made of light metal, the same as the blower casing.

There now follow several figures showing complete supercharging units. Fig. 5 shows a horizontal supercharging unit of the larger sizes for Diesel engines of about 700—1200 B. H. P., seen from the blower end. As a rule, the turbine casing and the turbine end bearing are water-cooled. The cooling water discharges from the water-cooled parts of the gas turbine are led to a common outlet and can be seen. For locomotive and railcar Diesels special designs are available without water-cooling.

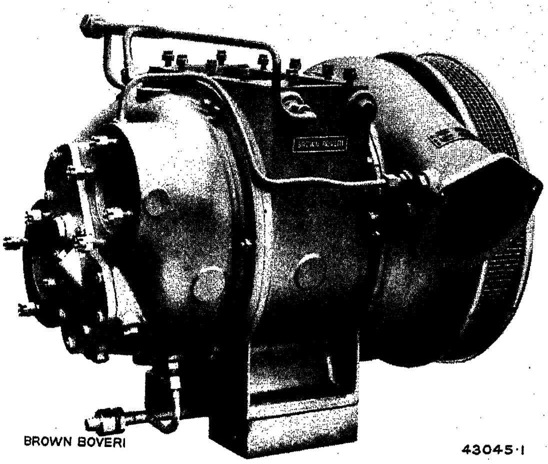


Fig. 6. — Horizontal supercharging blower unit, Brown Boveri design, for Diesel engines of small output.
With two gas inlet branches, seen from gas turbine end.

Fig. 6 shows a smaller unit for engines of about 400—700 B. H. P. seen from the gas-turbine end.

Due to the subdivision of the exhaust gas manifold, this unit is provided with two gas inlet branches and the same number of gas chambers which are kept separate right up to the nozzle ring. The complete separation of the exhaust pipes and exhaust chambers is essential in order to avoid balancing out of the pressure waves between the two and hence causing a disturbance of the scavenging. On the other hand, the discharge of the exhaust gases from the turbine casing is from a common branch.

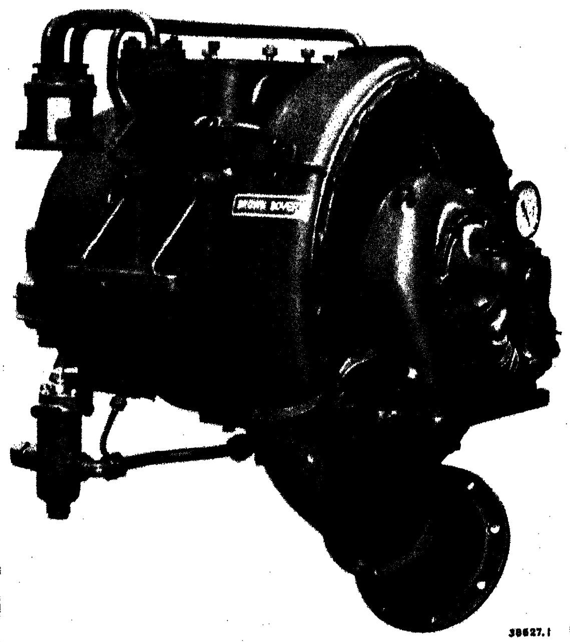


Fig. 5. — Horizontal supercharging blower unit, Brown Boveri design, for Diesel engines of moderate output. (Over about 700 B. H. P.) Looking from blower end.

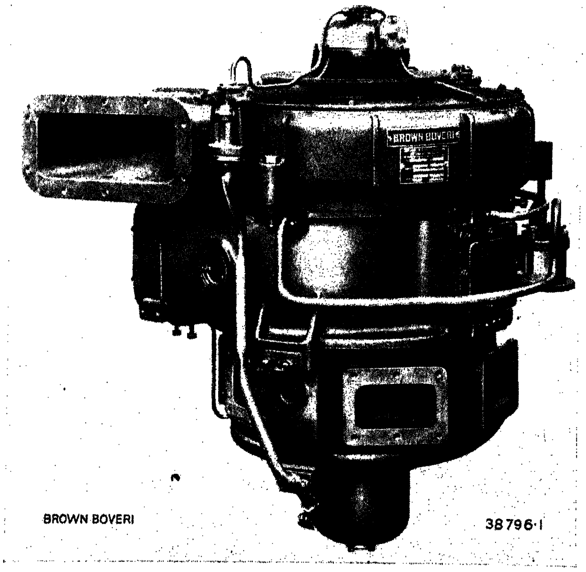


Fig. 7. — Vertical supercharging blower unit, Brown Boveri design.
20 of these units have been supplied for MAN Diesel engines, Type W 10 Vu 30/38. Output 1800 B. H. P. continuously, 700 r. p. m. They are destined for 10 coast guards for the Mexican Government. To suit the number of cylinders, 4 exhaust manifolds and 4 exhaust gas inlet branches on the turbine are provided (see also Fig. 12).

The supercharger units are so designed that, with alterations to a few small parts, they can also be arranged vertically.

Figure 7 shows such a vertical unit.

Particular attention has recently been directed towards *making the supercharging unit, as far as possible, an integral part of the Diesel engine.*

Formerly the supercharging unit was, as a rule, installed separately from the Diesel; today this is only the case with very large units.

Fig. 8 shows the largest Diesel installation with Büchi supercharging, i. e. that of the motor passenger vessel "Reina del Pacifico" with four Harland & Wolff — Burmeister & Wain trunk-piston engines, each of 5500 B.H.P. supercharged. Although the engines are of the twelve-cylinder type the exhaust piping is only divided into two parts. As two cylinders fire simultaneously, the engine can, therefore, be considered as a six-(double) cylinder unit. The supercharging unit is arranged at the same level as the cylinders. The charging-air manifold can be seen above the engine whilst the two exhaust lines are arranged along the engine, at a lower level. After leaving the turbine, the exhaust gases pass through a waste-heat boiler since they still contain a large amount of useful heat. Taking into account the waste heat conserved, overall thermal efficiencies of well over 40 % are obtained.

Fig. 9 is an example of a large, stationary Diesel with Büchi supercharging built by the S.L.M. Winterthur. In this case also the supercharging unit is built separate from the Diesel and is installed at engine-room floor level. The exhaust gases discharge downwards.

Stationary engines with supercharging are, today, used very often in plants which are installed at a considerable height above sea level (South America, Central India) in which cases the primary object of supercharging is to com-

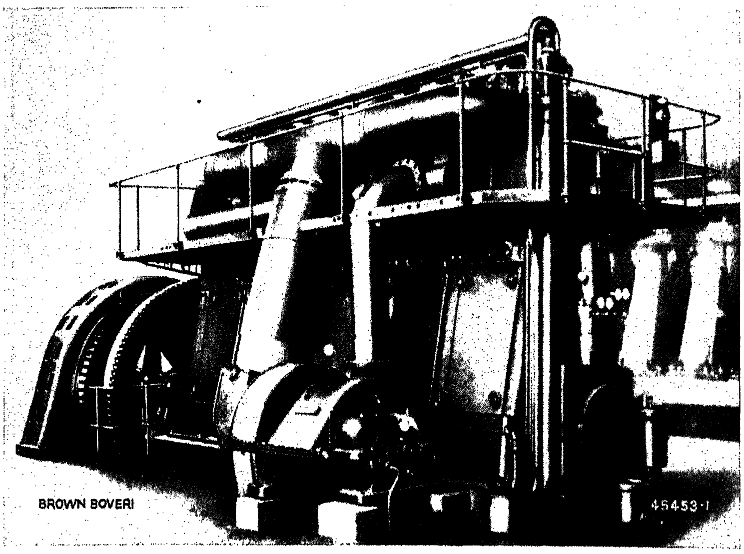


Fig. 9. — 1500 B. H. P.-Diesel engine built by the S. L. M. Winterthur, provided with Büchi supercharging and Brown Boveri exhaust-gas turbo blower unit in the power station of the Visayan Electrical Supply Co., Cebu, Philippines.

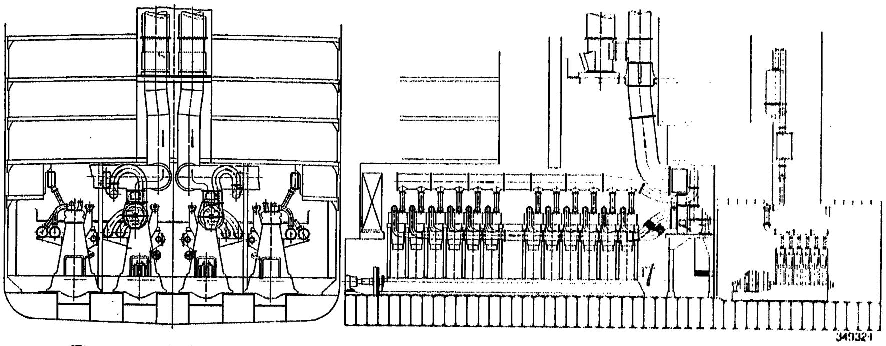


Fig. 8. — Machinery installation of the motor passenger vessel "Reina del Pacifico". With four trunk piston Diesel engines, each designed for 5500 B. H. P., 145 r. p. m. (22,000 B. H. P. total).

The engines (twelve-cylinder 630/1200) were built by Harland & Wolff, Belfast, and are provided with Büchi supercharging. The supercharging blower units supplied by Brown Boveri are installed at the same level as the cylinders independently of the Diesel engine. The exhaust gases after leaving the gas turbine are used for generating steam in waste-heat boilers.

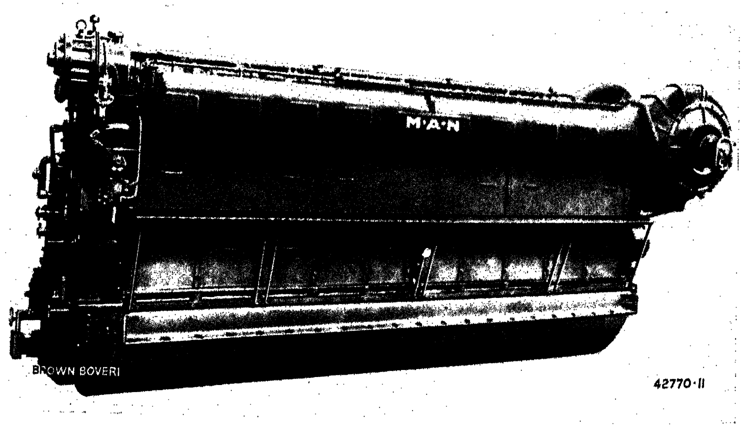


Fig. 10. — Ten-cylinder MAN Diesel engine with Büchi supercharging 1800 B. H. P., 700 r. p. m., M. E. P. 8·6 kg/cm².

The supercharging unit of Brown Boveri design is integrally combined with the Diesel engine to form a single unit. View from blower end showing the air manifold.

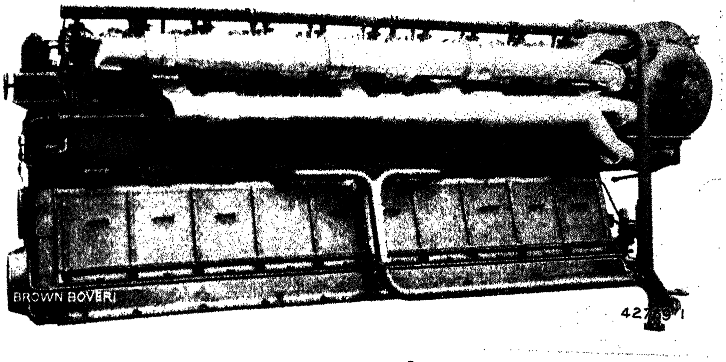


Fig. 11. — The same machine as Fig. 10 but seen from the exhaust side.
The ten cylinders are subdivided into four groups. The two exhaust manifolds are fitted with an internal partition; before entering the gas turbine they split into four individual exhaust pipes.

pensate for the loss in power due to the low density of the air. Stationary supercharged Diesels are also often used, however, as peak-load machines in power stations, due principally to their ability to carry heavy overloads. Because of this, supercharged 4-stroke engines have also often been installed for driving wood pulping machines.

Fig. 10 shows a quite modern supercharged Diesel in which the supercharging unit forms an integral part of the engine. The unit in question is a ten-cylinder MAN Diesel 1150 B. H. P. unsupercharged, 1800 B. H. P. continuous when supercharged, at 700 r.p.m. This type of unit is also built with 6, 8 and 12 cylinders, and is principally used for marine and traction purposes, but also for others. The air manifold in this case is arranged on one side of the engine as a direct continuation of the blower discharge branch. The exhaust-gas side can be seen from Fig. 11. The cylinders are subdivided into four groups. The two exhaust manifolds shown in the illustration are each subdivided by an internal plate. Just before the turbine, these split up into four separate pipes. It is very striking on looking at the figure that, due to the small blower unit incorporated, as much power is developed as corresponds (in weight and space) to half the machine. The same type of engine has also already been built with a vertical supercharging unit (Fig. 12).

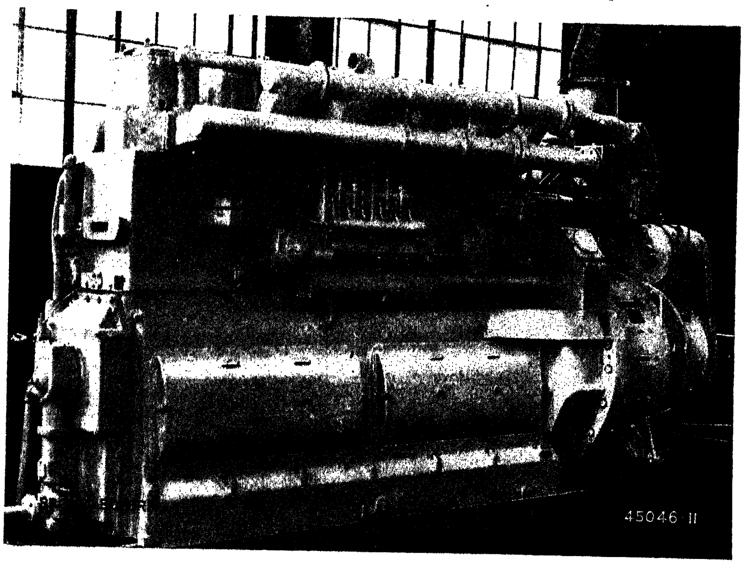


Fig. 13. — Six-cylinder traction Diesel engine with Büchi supercharging made by the American Locomotive Co., Auburn (U. S. A.).
The supercharging blower, supplied by Brown Boveri, is situated above the generator. No additional ground space, therefore, is required. Output of the engine 600 B. H. P. without 900 B. H. P. with supercharging at 700 r. p. m.

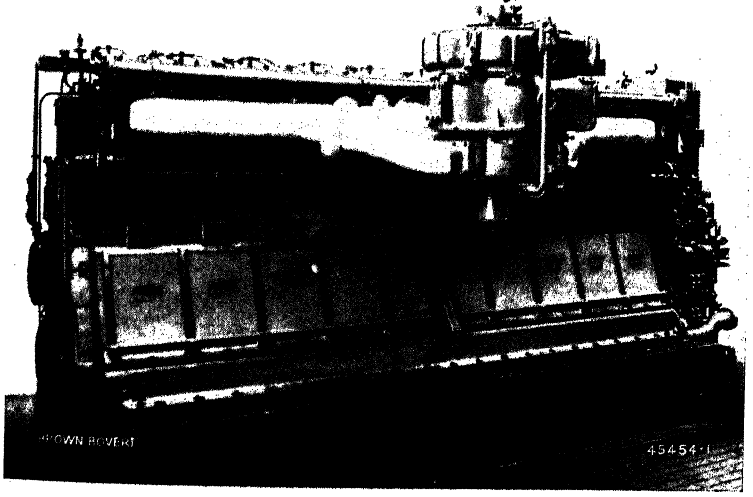


Fig. 12. — Ten-cylinder MAN marine Diesel engine with Büchi supercharger and vertical Brown Boveri supercharging unit. (See also Fig. 7.)

Fig. 13 shows a modern six-cylinder 318/330 mm traction Diesel engine made by the American Locomotive Co., Auburn, which develops a power of 600 B. H. P. without supercharging and 900 B. H. P. with supercharging at 700 r. p. m. Fig. 14 represents the Diesel engine with its supercharging unit erected on the locomotive frame, Fig. 15 is a photograph of the finished locomotive. At the present time, a whole series of such engines is in course of construction for shunting locomotives. As in the previous figure, the supercharging blower is arranged across the engine with the air piping on one side and the exhaust

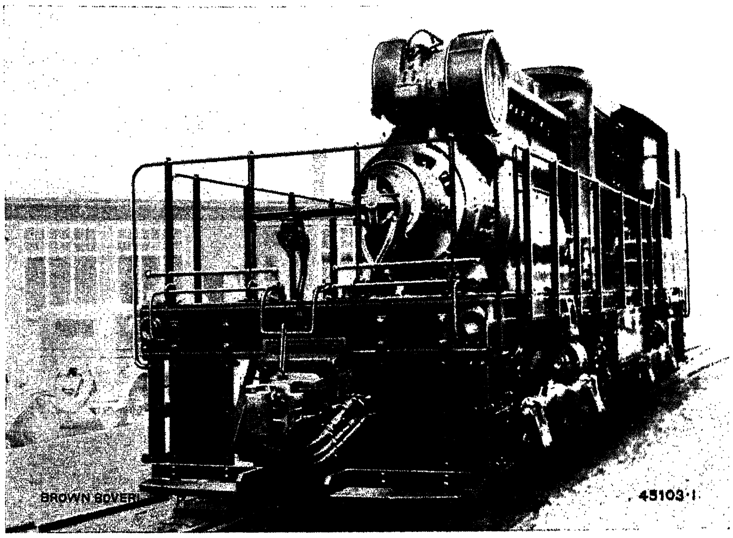


Fig. 14. — Alco-Diesel engine set (Fig. 13) with Brown Boveri exhaust turbocharger erected on the frame of a shunting locomotive.

piping on the other. In this case, however, the blower unit is supported on the generator. The 50 % additional power is, therefore, obtained without using any additional floor space. This is of considerable importance particularly for Diesel locomotives and railcars. In many cases it is only by the use of supercharging that the necessary power can be obtained from the Diesel engine within the limits of space available and permissible weight.

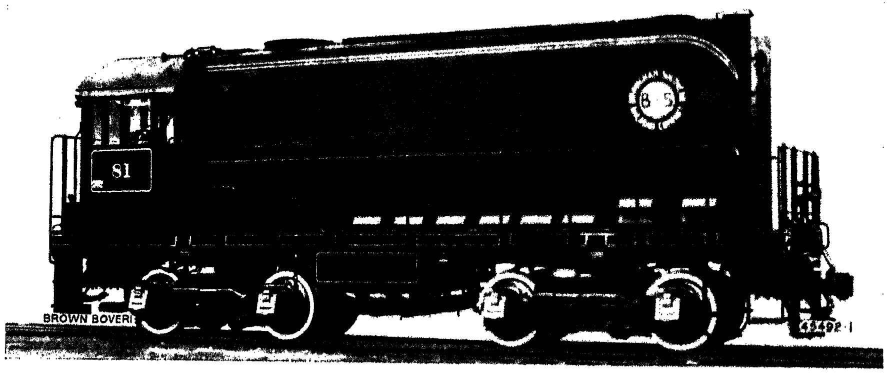


Fig. 15. — American shunting locomotive with Alco-Diesel motor provided with Büchi supercharging.

Fig. 16 also shows a particularly good example of the assembly of the supercharging unit with the Diesel engine. The unit shown is a Sulzer locomotive Diesel with Büchi supercharging. It can be clearly seen, in this case also, that the increase in power is obtained without requiring any additional floor space.

In the unit shown in Fig. 17 which is again a Diesel engine of American construction with Büchi supercharging, the supercharging blower is arranged on the side of the engine at the rear end and is parallel to the Diesel crank shaft, an arrangement which avoids increasing the overall length of the Diesel engine.

Fig. 18 shows a MAN Diesel for traction purposes of which the power was increased from 420 to 600 B. H. P. and of which a considerable number has already been built. The supercharging unit is arranged vertically between the cylinders, which are in two rows. As already mentioned, the supercharging units for traction purposes are, if necessary, made without water cooling and in a particularly light construction. This is the case in the present example. The turbine casing was made of heat-resisting steel plate and insulated. Bearings and shaft are air-cooled; an air circulation is arranged between the turbine insulation and the connecting casing between the upper and lower bearings. A similar arrangement is also used on many Maybach railcar engines.

The next figures are of smaller Diesel engines. Fig. 19 is a Deutz

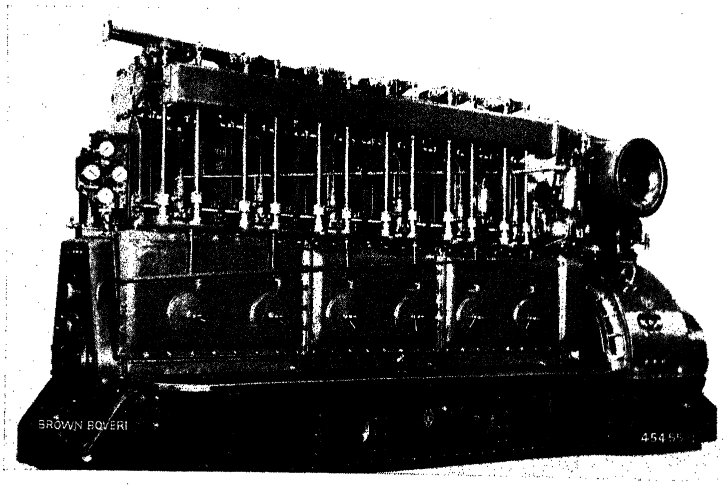


Fig. 16. - Six-cylinder locomotive Diesel engine, Type 6 LDA 28, made by Sulzer Bros. Ltd., Winterthur, with Büchi supercharging and Brown Boveri exhaust-gas turbo-blower unit.
The engine is installed in a goods locomotive of the Swiss Federal Railways (six-cylinder 280/340 mm, 600 B.H.P. at 610 r.p.m.).

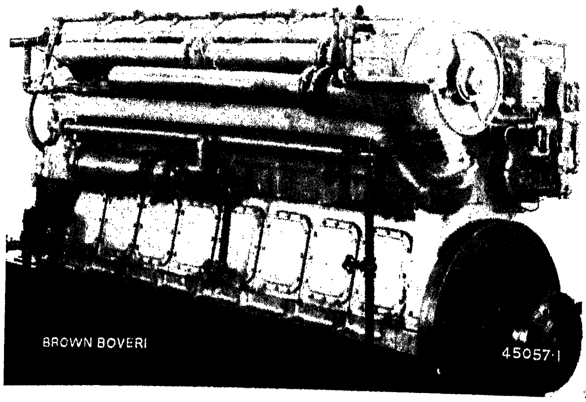


Fig. 17. — **Four-stroke Diesel engine of the Cooper-Bessemer Corporation, Mt. Vernon (Ohio, U. S. A.) with Büchi supercharging and Brown Boveri exhaust-gas turbo blower.**

8 cylinders, 8" × 10½", without supercharging 320 B.H.P. 700 r.p.m. (M.E.P. = 5·95 kg/cm²). With supercharging, 450 B.H.P. continuously, (M.E.P. = 8·37 kg/cm²), 500 B.H.P. for one hour (M.E.P. = 9·28 kg/cm²), 700 r.p.m.

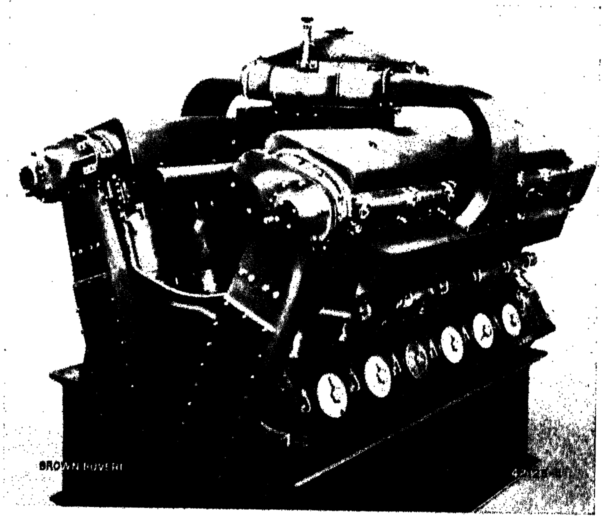


Fig. 18. — **MAN twelve-cylinder V type traction Diesel with Büchi supercharging provided with a vertical supercharging unit of Brown Boveri design without water cooling. Capacity 560/600 B. H. P. 1400 r. p. m.**

marine Diesel of 275 B. H. P. at 725 r. p. m. In this case the air- and exhaust-gas piping are arranged on the same side.

Fig. 20 represents a Saurer traction Diesel engine Type BXD, which is also a good example of an organic combination of the Diesel with the supercharging unit.

Finally, Fig. 21 shows the smallest supercharged Diesel engine so far built, for a Saurer traction Diesel having six cylinders 110 bore, 150 stroke, giving a maximum power without supercharging of 100 B. H. P. and, with supercharging, of 160 B. H. P. at 1800 r. p. m. Since the supercharging blower weighs about

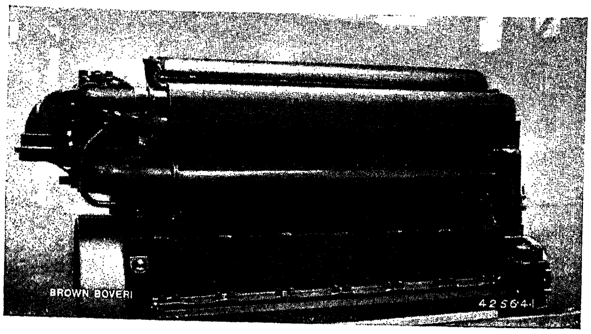


Fig. 19. — **Six-cylinder marine Diesel Deutz design with Büchi supercharging and Brown Boveri supercharging blower unit.**
Capacity 275 B. H. P., 725 r. p. m.

The exhaust gas and air manifolds are arranged on the same side of the engine. As the supercharging blower unit is arranged above the coupling, the additional power is obtained without increasing the floor space taken up. Two of these engines have been installed in the Rhine vessel "Albert Leo Schlageter" for the Cologne Dusseldorf Rhine Steamship Co.

30 kg including the additional piping required, the additional power is obtained with an increase in weight of barely 0·5 kg/B. H. P.

IV. TEST RESULTS ON FOUR-STROKE DIESEL ENGINES WITH BÜCHI SUPERCHARGING.

Some of the *practical results* obtained with Büchi supercharging of the various types of Diesel engines are given hereafter. Fig. 22, which shows the results of tests on a Saurer high-speed traction Diesel type BXD, $6 \times 130/180$ (see Fig. 20), indicates the fuel consumptions which can be obtained with Büchi supercharging. In this figure two machines of the same power with and without supercharging at the same speed are compared with one another. The comparison does not, however, refer to the same machine as the unsupercharged engine may obtain the same power with more cylinders or with different cylinder dimen-

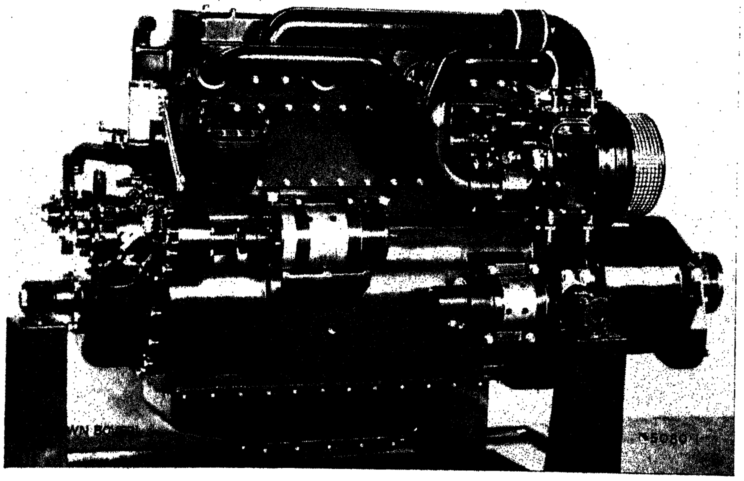


Fig. 20. — **Saurer traction Diesel engine, Type BXD, with Brown Boveri supercharging unit Type VTx 201.**
Diesel engine 6 cylinders, 130/180 mm; max. output with supercharging 225 B.H.P. at 1500 r.p.m. (see also Fig. 23).

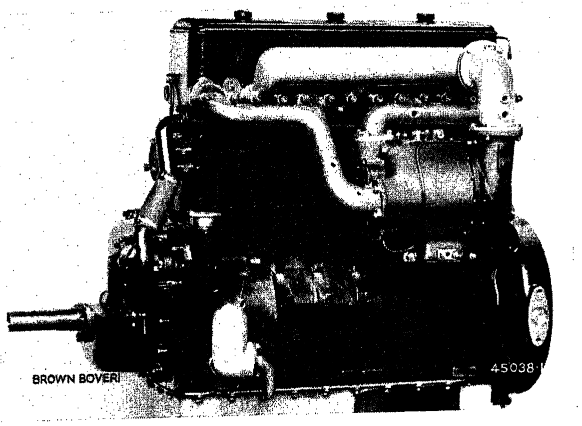


Fig. 21. — Saurer traction Diesel engine (6×110/150) with Büchi supercharging.

Maximum capacity 100 B.H.P. without supercharging, 160 B.H.P. with supercharging at 1800 r.p.m. This unit is the smallest Brown Boveri supercharger and the smallest Diesel which has so far been fitted with exhaust-gas turbo supercharging.

sions and stroke. As will be seen the supercharged engine is definitely better with regard to fuel consumption than that working without supercharging and the improvement is so much the greater the higher the speed. Whilst the specific fuel consumption of the unsupercharged engine at the most favourable condition increases rapidly with increasing speed, in the case of the supercharged engine even at high speeds, it remains always low, a result which shows better than any other the favourable effect of supercharging on the Diesel, in particular on the combustion process. It can be said that a satisfactory high-speed Diesel engine is only possible with supercharging[1] and further, that even in this particular field the 4-stroke Diesel with exhaust-gas turbo supercharging shows a definite superiority over the 2-stroke engine.

[1] See also Nägel: "Considerations in connection with the possibility of high speed Diesels". (Z. VDI 1936, page 1036.)

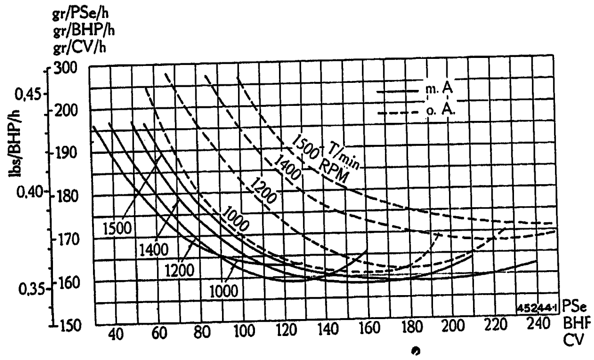


Fig. 22. — Fuel consumption of high-speed traction Diesel engines of the Saurer BXD type without and with Büchi supercharging.

The comparison is not based on one and the same engine but on two engines of different dimensions or number of cylinders of which one gives a maximum power of 225 B.H.P. at 1500 r.p.m. as a normal engine (fuel consumption curve o.A.) whilst the other is built as a supercharged engine (fuel consumption curve m.A.). The large increase in fuel consumption with speed of the unsupercharged engine is striking, whilst the supercharged engine shows a consistently low fuel consumption over the entire speed range. For high speed engines, supercharging is indispensable for giving good combustion.

Fig. 23, which is based on test results from various types of 4-stroke Diesels, shows the average conditions which can be obtained with exhaust-gas turbo supercharging under the Büchi system when the Diesel engine is correctly designed (good combustion, adequate valve area).

The results and hence also the advantages of Büchi supercharging can be summarized briefly on the basis of these figures as follows:

(1) With a Diesel engine of a given weight and dimensions increases in load of 40—50 % *continuously* and up to 80 % and over at peaks are obtainable without exceeding the permissible thermal or mechanical stresses in the engine[1]. Pflaum[2] states on the basis of the latest investigations by MAN: "We have established that the heat stresses reach the same figure as with the unsupercharged engine at a M. E. P. of 9·5 kg/cm², that is, at an increase in power of 70 %."

[1] See the conclusions in the article by Stodola:— "Power tests on a Diesel engine with Büchi supercharging". Z. VDI No. 13/1928, page 421.

[2] Pflaum, see Footnote 1, page 176.

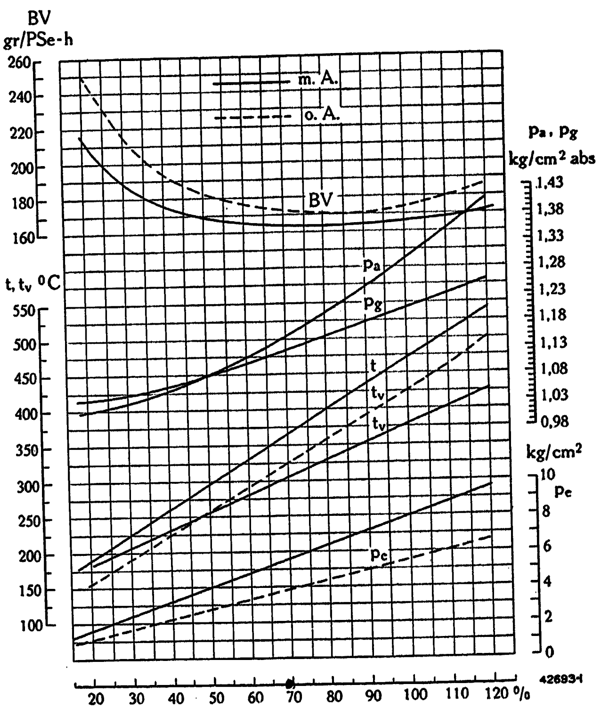


Fig. 23. — Test results with Büchi supercharging on 4-stroke Diesels and comparison with unsupercharged engines.

Abscissae: Load on engine in percent.
Ordinates:—

BV. Fuel consumption in g/B.H.P.h.
pa. Pressure of supercharged air in kg/cm² abs.
pg. Mean pressure of exhaust gases entering the turbine in kg/cm² abs.
t. Temperature of exhaust gases entering turbine in °C.
tv. Temperature of exhaust gases leaving exhaust valves in °C.
pe. Mean effective pressure of Diesel engine in kg/cm².
oA. Without supercharging.
mA. With supercharging.

(2) The fuel consumption is lower and the fuel-consumption curve at partial loads is much flatter than with an unsupercharged engine.

(3) The Diesel engine is as flexible with regard to changes in load as a steam engine, it responds readily to heavy peak loads, since the charging blower adapts itself to every change in load without external adjustment and practically instantaneously (Fig. 24). More power requires more fuel; more exhaust gases are developed which are also at a higher temperature, the turbine speed increases and the blower delivers more air at a higher pressure and vice versa.

(4) Less maintenance cost (exhaust valves, cylinder covers) and since the supercharged engine is considerable smaller in dimensions than a normal Diesel of the same power, less lubricating oil and cooling-water consumption. The exhaust is free from smoke and silent at all loads. The exhaust gas turbine has in actual fact proved itself as an excellent silencer.

(5) The supercharged 4-stroke engine can be run up from the cold state, and after long periods of standing idle, more quickly and safely than any other Diesel of the same power (smaller dimensions, reduced friction forces on the piston rings).

(6) For powers above about 300 B. H. P. the supercharged Diesel is also cheaper than a normal Diesel. Büchi supercharging, however, due the many

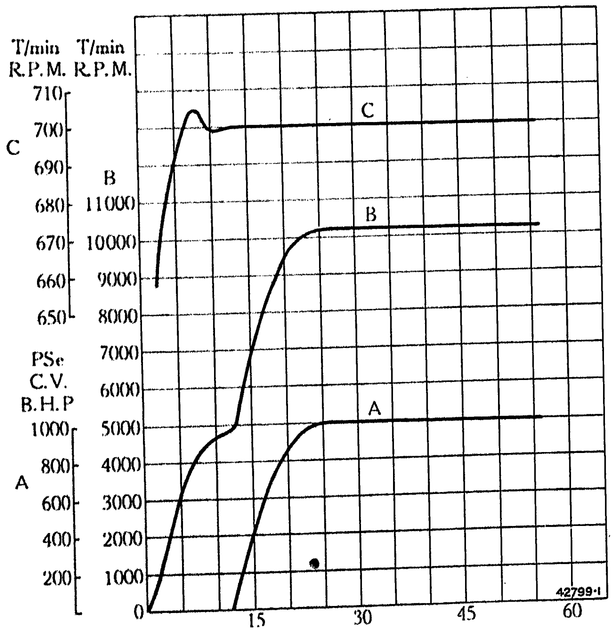


Fig. 24. — Starting time of a supercharged 1000 B. H. P. MAN Diesel engine with exhaust-gas turbo blower.

Abscissae: Time in seconds.
Ordinates:—
A. Effective output of Diesel engine.
B. Speed of turbo-blower unit.
C. Speed of Diesel engine.

The speed of the supercharger unit follows changes in load of the Diesel engine practically instantaneously.

other advantages it possesses is also used for smaller Diesels, already in present-day practice down to about 100 B. H. P.

Heat balance of a 1000 B. H. P., 700 r. p. m. MAN 4-stroke Diesel engine with Büchi supercharging at various loads (constant speed). [1]

Values expressed as percentages of the heat in the fuel supplied				
Load (M. E. P. in kg/cm²)	**5·6**	**8·0**	**10·0**	**5·6 Unsupercharged Diesel engine**
	%	%	%	%
Useful power . . .	38·5	39·5	38·0	38·0
Carried away in cooling water (cylinder cooling and lub. oil)	17·5	15·1	14·7	26·6 *
Carried away in gas turbine cooling water	2·2	2·8	3·9	—
Heat in exhaust gases leaving gas turbine	36·4	35·1	34·4	30·8
Residual losses . .	5·4	7·5	9	4·6
Total	100	100	100	100

* Including exhaust piping.

It should be particularly remembered that Fig. 23 gives good average values and that in individual cases still better results were obtained, e. g. fuel consumptions down to 155 g/B. H. P. h.

Unfortunately, due to lack of space, a comparison with other supercharging systems cannot be gone into here. This matter has been dealt with by Pflaum[2] and only the following brief comment will be given here. All other systems have this in common:— Since the supercharging blower is driven by the Diesel engine itself or the underside of the piston is used as an air compressor, then an increased cylinder power, i. e. an increased fuel consumption, is necessary for supercharging and scavenging. It can, therefore, be quite definitely stated that no other supercharging system is so economical as the Büchi system. Also, no other system is so simple, the exhaust-gas turbo blower can be placed at any point in the exhaust-gas line, independent of the Diesel engine, it governs itself automatically due to its thermal coupling with the engine; apart from certain slight modifications (increased size of fuel pump, modified valve setting) the Diesel engine is unaltered so that at any time an existing 4-stroke engine can be fitted with Büchi supercharging. Such a conversion can be carried out simply for creating more power or to reduce the stresses

[1] Pflaum, see Footnote 1, page 176.

[2] Pflaum "Supercharged Diesel engines and ship propulsion", "Werft, Reederei, Hafen", No. 12/1935.

in an existing engine for the same or only slightly increased load. With all other systems the driving of the blower from the Diesel is an undesirable complication, and for engines which are subjected to much manœuvring, requires careful thought to ensure reliability of operation. The pressure and volume of the charging air does not adapt itself to the load conditions. If the conditions are right for normal load then they are less favourable at partial loads and give rise to a relatively large increase in the steepness of the fuel-consumption curve.

V. TWO-STROKE DIESEL ENGINES AND EXHAUST-GAS TURBO SUPERCHARGING.

All 2-stroke engines, today, already operate with a certain degree of supercharging. Depending on the type of engine and the speed, the scavenging pressure amounts to 1·15—1·4 kg/cm^2 abs and most engines are provided with arrangements which bring each cylinder in turn, after the scavenging process, once more into communication with the scavenging-air container so that the cylinder is filled with air at the scavenging-air pressure, before compression proper starts. Hence, the power consumption for scavenging and charging is very high and in the case of high speed 2-strokes may be up to 15 % of the Diesel capacity.

A satisfactory method using exhaust-gas turbo supercharging on 2-stroke engines has not yet been found. Various firms have made attempts to solve this problem. It is, however, not simple, first, the temperature of the exhaust gases, due to their mixing with the scavenge air, is very much lower than with the 4-stroke engine, hence the power developed by the exhaust gas turbine is small. It has even been proposed to tap off hot exhaust gases, before expansion is completed in the Diesel cylinder, for the gas turbine. In order to keep down the power required by the blower, scavenging should be carried out at low pressure and supercharging at high pressure, which would require a multi-stage blower with two discharge branches. Moreover for a 2-stroke engine the air for combustion and the scavenging air must already be present before the exhaust gases are available, i. e. a starting motor or, in other words, a dual drive must always be provided.

Brown Boveri have offered a solution which is at least a step in the right direction and above all, makes it possible to increase the power of existing 2-stroke engines. This is the so-called Curtis scheme of which the European patents have been acquired by Brown Boveri. The system simply consists in arranging an exhaust-gas turbo blower before the existing scavenge pump (reciprocating pump or centrifugal blower) so that they work in series (Fig. 25).

VI. THE SUPERCHARGING OF AEROPLANE ENGINES.

Unfortunately, due to space available, even this extremely important field for supercharging can only be dealt with very briefly. It is well known that the power of an aeroplane engine, or in general, of any combustion machine, decreases rapidly with height above sea level (Fig. 26). Attempts are continually being made to achieve greater flying heights, since the resistance to flight becomes less with increasing height, hence for a given engine power,

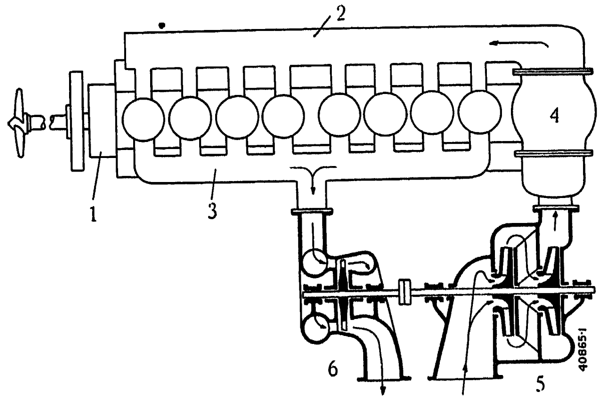


Fig. 25. — Supercharging of 2-stroke Diesel engines by the Brown Boveri-Curtis (pat.) system.

The compression of the scavenging and supercharging air is carried out in two blowers arranged in series, of which one is driven by the engine itself or another source, the other by an exhaust gas turbine.

1. Diesel engine.
2. Scavenging-air pipe.
3. Exhaust-gas pipe.
4. Built-on piston-type scavenging-air blower.
5. Charging blower.
6. Exhaust-gas turbine.

much greater flying speeds can be obtained. With military aeroplanes also height is an advantage from the point of view of reduced visibility of the machine. All modern aeroplane engines are, therefore, fitted with supercharging blowers, these being centrifugal blowers which are driven from the engine by gearing. These mechanically-driven supercharging blowers are incorporated with the aeroplane engine. The direct driving of the supercharging blower from the engine is uneconomical in this case also, since as already mentioned, it necessitates an increase in fuel consumption. Also the driving of the blower from the engine absorbs part of the increased power developed. Due to this the net power developed by the aeroplane engine finally decreases rapidly with increasing flying height even with mechanically-driven superchargers, so that above a height of about 5000 metres, this type of supercharging gives a continuously decreasing additional power which eventually disappears altogether. *For flying at great heights the exhaust-gas turbo blower is the only solution and in time it will definitely be adopted.* The heights which will then be able to be reached with single and two-stage blowers are shown in Fig. 26.

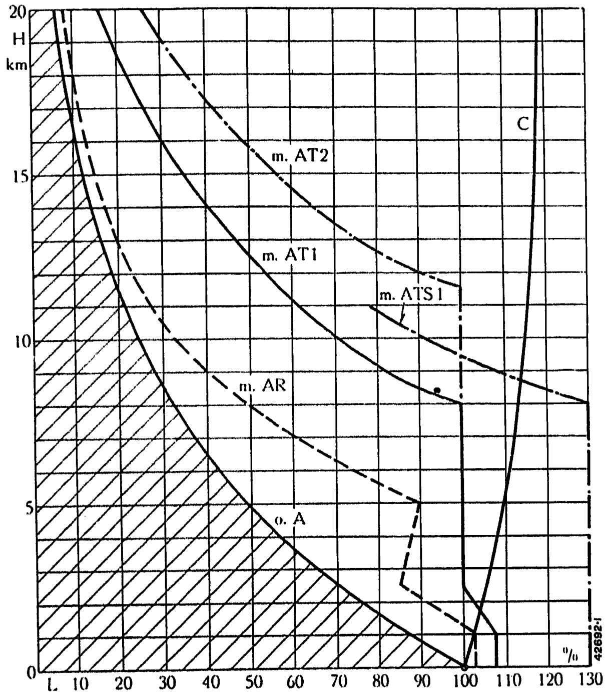


Fig. 26. — Decrease in power of aeroplane engines with height.

Ordinates:— H. Flying height in km.
Abscissae:— L. Power in percent where 100% ground level power without supercharging.

o. A. Power without supercharging.
mAR. Power with supercharging; single-stage blower driven through gearing by the engine.
mAT_1. Power with supercharging, single-stage exhaust gas turbo-blower, *no* scavenging.
mAT_2. As above but 2-stage blower.
mAT_1S. As mAT_1 but *with* scavenging.
C. Power with supercharging using exhaust-gas turbo blower if the air pressure entering the carburettor is kept constant and equal to that at ground level.

Supercharching by means of exhaust-gas turbo blowers is more difficult with aeroplane engines than in the case of Diesels for the following reasons:—

(1) Modern aeroplane engines are mostly petrol engines which, with the present construction, do not permit of scavenging (Brown Boveri have a patented solution which enables scavenging to be used, but which requires modifications to the design of the aeroplane engine and which, due to this, has not yet been applied in practice).

(2) The exhaust gas temperatures are of the order of 850° C as compared with 500° C in Diesel engines.

(3) In this case, the question of weight and space is of supreme importance.

With regard to point (1) it may be said that in the future, sooner or later, the change-over will take place to the petrol engine with direct injection or to the Diesel engine. When this occurs, the conditions will be exactly as at present with high-speed Diesel engines, i. e. exhaust-gas turbo charging can be used exactly in accordance with the principles of the Büchi system.

Up to the present we must consider the aeroplane engine, as it is, now, still almost always constructed, i. e. with carburettor and without any possibility of scavenging, hence with very high exhaust-gas temperatures. Brown Boveri have at present in construction a number of blowers for aeroplane engines for various firms (Fig. 27). Broadly speaking, the construction of these supercharging blower units is exactly the same as that for the Diesel engine exhaust-gas turbo blowers described, i.e. the gas turbine and blower are on the same shaft which, in this case also, is supported in ball bearings. With the aeroplane engine supercharger, however, a considerable amount of thought has been taken to give as great a reduction of the weight as possible. The excess air which would otherwise be used for scavenging the compression space, is here used for cooling the gas turbine blades (gas and air nozzles alternately delivering to the turbine wheel) or simply mixed with the exhaust gases before they enter the turbine in order to give permissible temperature conditions.

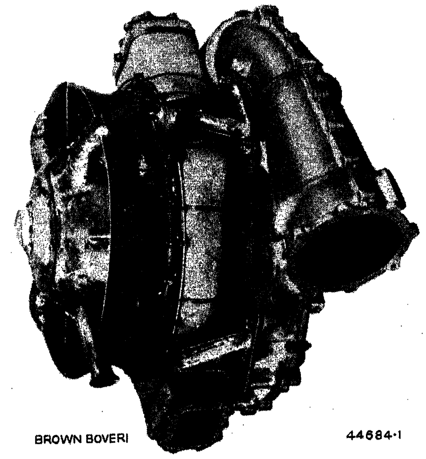


Fig. 27. — Brown Boveri exhaust gas turbo-blower, light construction for aeroplane engines (carburettor types).

For an aeroplane engine which still develops 400 B. H. P. at a height of 8000 m, the supercharging blower unit weighs about 32 kg.

VII. FURTHER POSSIBILITIES OF THE APPLICATION OF EXHAUST-GAS TURBO SUPERCHARGING AS A MEANS OF INCREASING POWER (BOILER COMBUSTION, HEAT-EXCHANGING PROCESSES, CHEMICAL INDUSTRY).

In recent years supercharging as a means for increasing power has also been used in other applications. It is well known that Brown Boveri have applied supercharging in the Velox steam generator to increase the combustion chamber output (Fig. 28). Further, the process of supercharging has also been applied in the

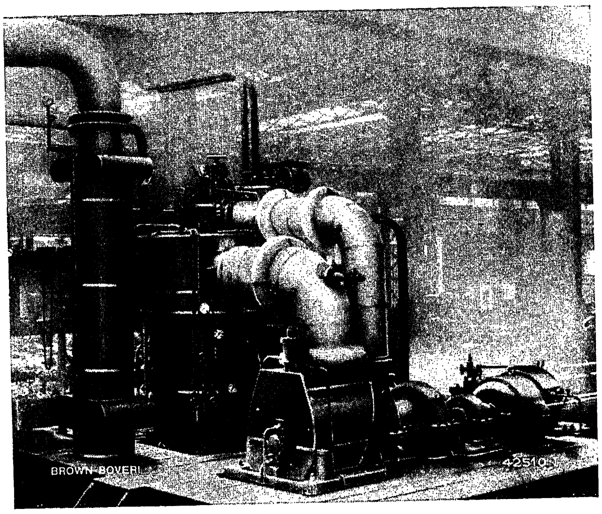


Fig.28.–Application of exhaust-gas turbocharging to boiler combustion.
Velox steam generator for an evaporation of 20 t/h on the test bed. The supercharging unit with gas turbine, axial compressor and starting motor is in the foreground. Supercharging of the combustion space enables heat releases up to 10×10^6 kcal/m³h to be reached, i. e. up to about 30 times that of normal boilers with combustion under atmospheric pressure.

chemical industry in order to increase the intensity of a chemical reaction or to increase the output of chemical apparatus. Supercharging is always combined with a chemical reaction; the combustion in a Diesel engine or in a steam generator is, actually, a chemical reaction and supercharging is a means for increasing this reaction both quantitatively and qualitatively. Quantitatively, in the sense that by compression of the gas or air, a greater weight of substance can be dealt with in a space of given dimensions (Diesel engine cylinder, combustion space of a boiler, reaction space of a chemical apparatus) or that the effectiveness of heat-exchanger surfaces is improved due to the higher density. Qualitatively, in the sense that the desired reaction takes place more completely, e. g. more complete combustion with minimum excess air is obtained or the effectiveness of catalysation is improved due to the more favourable conditions caused by supercharging.

It is once again stressed that all these supercharging processes are only economical if the energy for compression can be more or less completely obtained from the process itself without expenditure of external energy. In the same way as with the Diesel engine, in the Velox steam generator gases of combustion are available which give up some of their energy for driving the compressor, and in the chemical processes there are likewise hot gases available in the process itself which are expanded in the gas turbine coupled to the compressor, so supplying the necessary energy (Fig. 29). So long as the pressure of the exhaust gases is of approximately the same order as the compression pressure and the temperature of the gases is correspondingly high, the energy given up by the exhaust gases is sufficient for driving the compressor. With higher compression, however, with insufficiently high temperature and often also at partial loads, the power from the gas turbine is not sufficient and it is necessary to supply auxiliary heating or, more generally, auxiliary power from external sources. A further reason for this is that the power of the gas turbine is limited by the maximum permissible temperature entering the turbine. The present-day limit, as already stated, is about 600° C.

A *complete supercharging process* includes, therefore, not only the idea of compression but, strictly speaking, also the idea of *obtaining the energy for compression from the working cycle itself without consumption of external energy.*

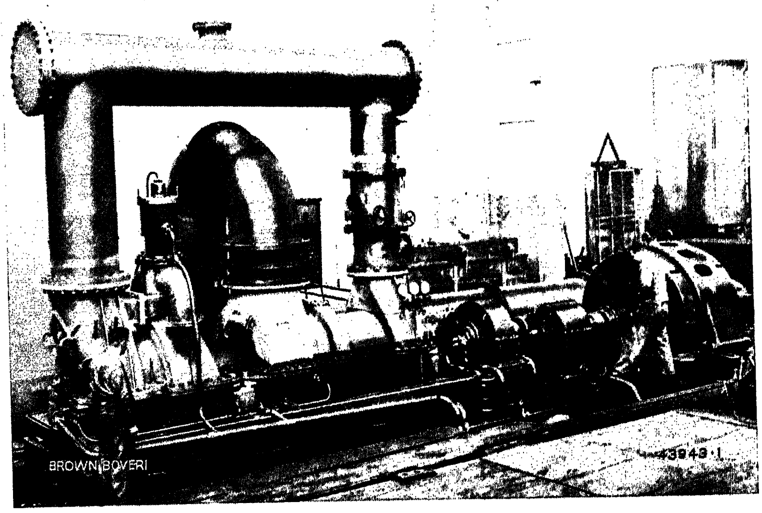


Fig. 29. — Brown Boveri supercharging unit with gas turbine for a supercharging process in the chemical industry. (Sun Oil Co., Philadelphia, U.S.A.).
The supercharging blower is a multi-stage axial compressor, the gas turbine develops about 7000 B.H.P.

These short notes and examples will serve to show that today the idea of supercharging is not confined to Diesel engines only but that the principle, as a universal means of power increase, is also being applied to many other fields of great importance.
(MS 541) *E. Klingelfuss.*

GEARED MOTORS AND MOTOR GEARS.

Decimal index 621. 313. 13—23. 621. 83. 065. 1.

IN order to reduce the speed of electric motors, which is too high for many types of drive, geared motors were brought out and used, as early as several decades ago. In accordance with the stage of technical development reached at that period, open spur-wheel gears were used, with one pinion made of raw hide to assure quiet running (Fig. 1). It will be readily understood that reduction gears of this design did not give satisfaction, in the long run, owing to their vulnerability to the effects of dust and damp and because lubrication was insufficient.

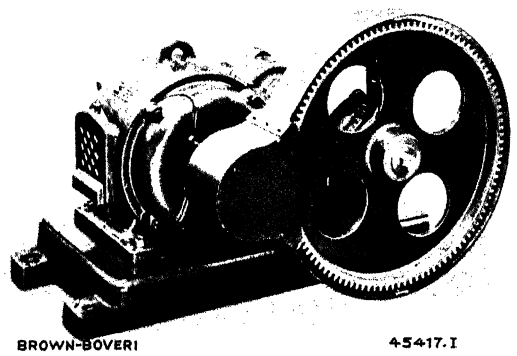


Fig. 1. — A geared motor of obsolete design.

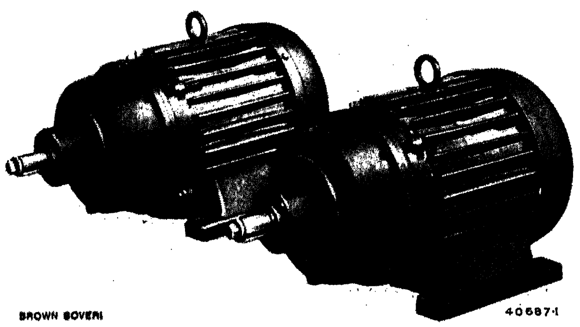


Fig. 2. — Three-phase geared motor totally enclosed Type MQUe/PA, of about 3 kW, 1450/160 r.p.m.

In modern *geared motors,* the reduction gear and the motor are so cleverly combined in one single machine that, as regards design, dimensions and other running qualities, it is difficult to distinguish them from an ordinary, gearless, electric motor (Fig. 2). The reduction gear is now lodged in the bearing shield of the motor and it can be built into motors for every kind of current and every design, open or totally enclosed (Fig. 3).

The use of planet gears allows of attaining a very pleasing co-axial arrangement of the wheels which only needs a minimum of space. In order to make the gear as noiseless as possible, the teeth of the various gear wheels are machined with the greatest possible care and cut on a slotting machine. According to the size and design of the gear, straight or simple inclined teeth with rectified face flank are used. The pinions are, generally, made of hard steel of a quality very resistant to wear, while the bigger gear wheels are either made of steel or of a special cast iron of great strength. The teeth themselves are so calculated that there is no wearing away of the face flanks under ordinary loads and that the teeth will not break under the very severe overloading met with in practice. The starting torque can be as high as $2—2^1/_2$ times the standard torque. All the gear wheels are carried on rolling bearings (ball, roller or roller needle bearings) which are amply designed. Apart from some special cases, the reduction gears can be driven, as is required, in one sense of rotation or the other.

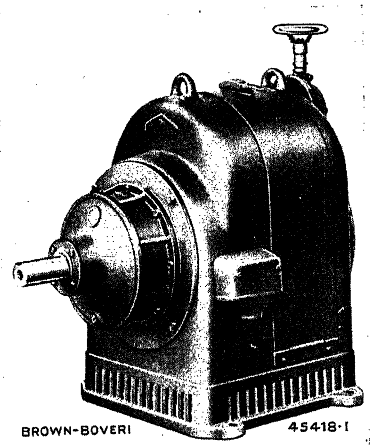


Fig. 3. – Shunt commutator motor with built-on planet gear, 4 kW, 1600 – 400 / 170—42·5 r.p.m.

All the parts of the inside of the reduction gears which are not machined are treated with a coat-

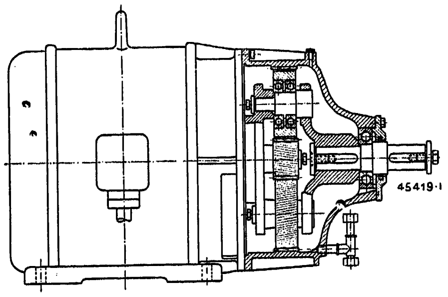


Fig. 4. — Geared motor with PA planet gear for speed ratios up to about 1 to 10.

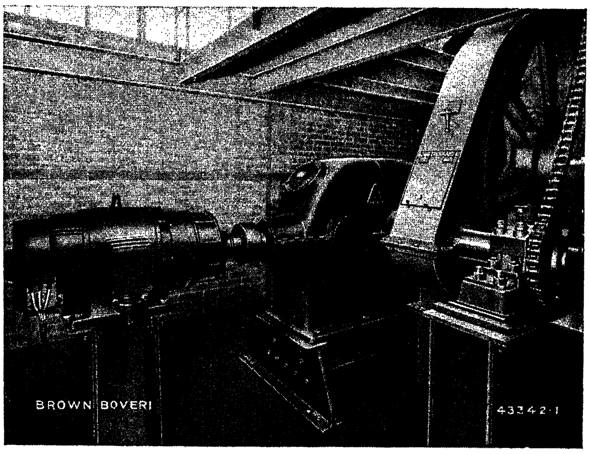


Fig. 5. — Drive of a concentrator in a cement mill by a three-phase geared motor of slip-ring type, 22 kW, 1450/300 r.p.m.

ing of oil-proof paint to prevent hard scraps of metal being detached from the surface of the casting. All the reduction gears, those for horizontal mounting as well as those for vertical mounting of the shafts, are oil-filled to provide for efficient lubrication of wheels and bearings. There are lateral openings in the housing allowing of supervision of the oil level, or else there is an oil gauge provided for that purpose. Grease lubrication is used for the bearings in special cases.

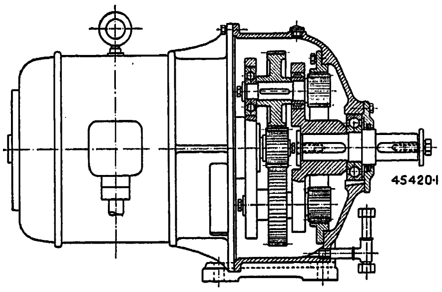


Fig. 6. — Motor gear with PB gear for speed ratios of about 1 to 12 up to 1 to 35.

The geared motor, the design of which is shown diagramatically in Fig. 4, is built for speed reductions down to about 1 to 10.* The gear casing, which is easy to take off, is bolted to the motor housing proper in the place of one bearing shield. The gear casing is tightly closed off from the motor, so that no oil can get into the motor.

For ratios of more than 1 to 10, the torque on the gear shaft gets so big that a rigid support of the gear case through those points where it is bolted to the motor housing is difficult to achieve. In such cases, the gear case is secured directly on the foundation and the motor is then flanged on to the reduction gear. This design really constitutes a *motor gear* in which every part which has to stand up to the big torque caused by the slow-running gear shaft is directly supported, through the feet of the gear case, while the motor and its securing bolts are entirely free of the stressing in question.

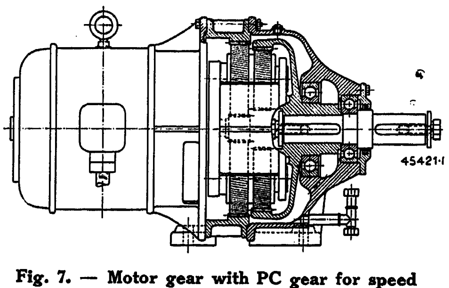


Fig. 7. — Motor gear with PC gear for speed ratios of about 1 to 35 up to 1 to 1000 and more.

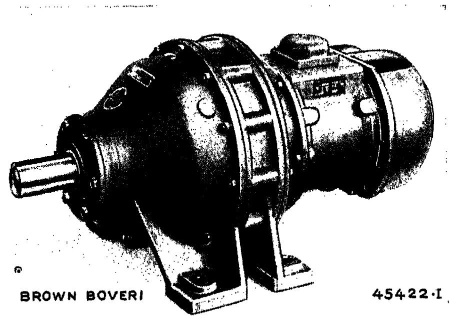


Fig. 8. — Motor gear, totally enclosed, Type PC/MUe, 2·1 kW, 1425/12 r.p.m.

According to the reduction ratio, there are different designs of gear. Fig. 6 shows a motor gear for ratios of about 1 to 12 up to 1 to 35, for a maximum torque on the shaft of the gear of about 700 mkg. Figs. 7 to 9 show gears for motors for ratios of above 1 to 35 up to 1 to 1000 for the smaller types and 1 to 3000 for the bigger types, which can be built for torques up to 1300 mkg.

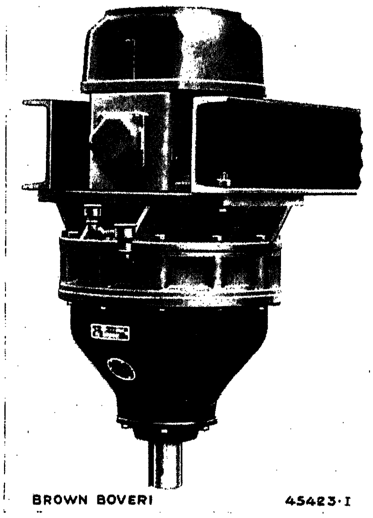


Fig. 9. — Vertical motor gear, totally enclosed.

According to the particular requirements of each case, modifications of these standard

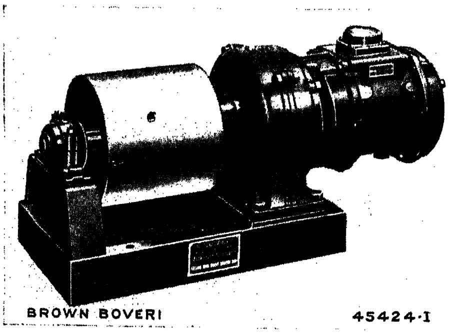


Fig. 10. — Frame-mounted motor gear with belt pulley and outside bearing, 3 kW, 1430/180 r.p.m.

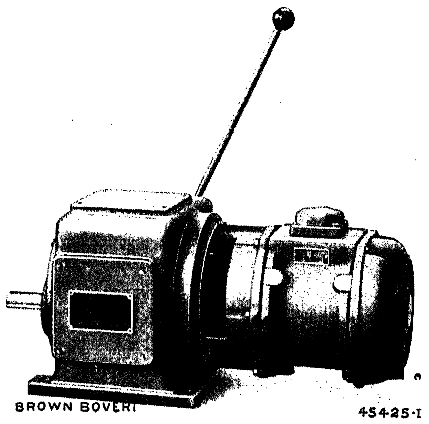


Fig. 11. — Stepped motor gear without control column.

designs are used. If, for instance, the gear shaft drives through the agency of a chain or belt and not through a coupling, either the bearing of the gear must be made stronger or an out-side bearing added (Fig. 10). In the case of heavy machines, both the motor and the gear casing are carried independently, while, in the case of relatively big motors, such as commutator motors, it sometimes happens that the gear with reduction ratios of more than 1 to 10 are secured to the motor and not supported on its own housing.

An interesting design is that of the stepped motor gear especially used for machine tools but also, frequently, for other industrial machinery. These gears can be delivered for 2—9 working speeds and with or without control columns (Figs. 11 and 12).

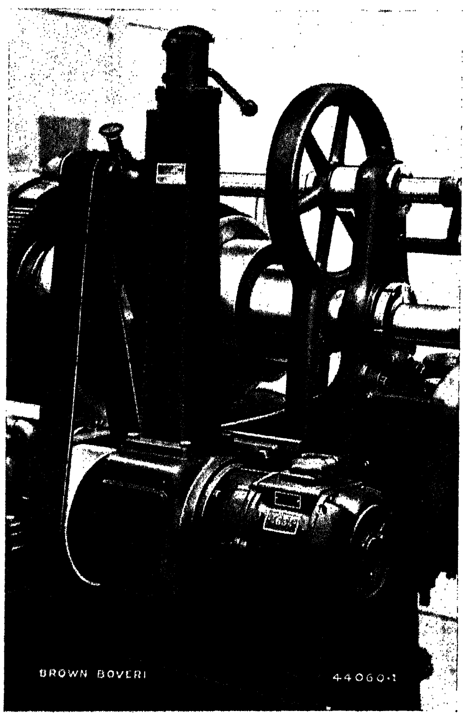


Fig. 12. — Stepped motor gear with control column, built on to a lathe.

There is a speed-changing reduction gear inside the oil and dust-tight gear casing, having hardened wheels of high-grade chrome-nickel steel. For high speeds, the wheels have ground teeth flanks. The switching over from one speed to another is carried out by means of a single control lever, which can be so mounted as to be easily used by the operator.

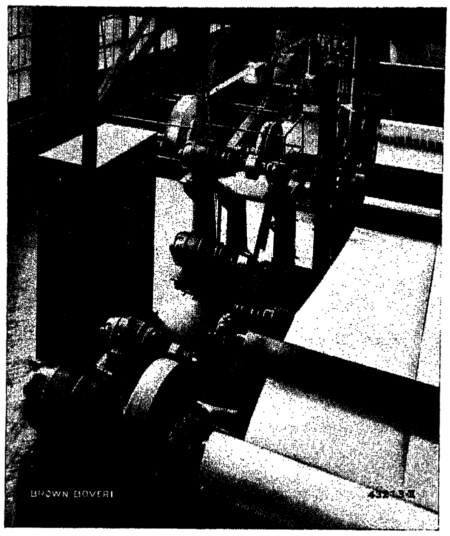


Fig. 13. — Sectional drive of cellulose dewatering machine.

The stepped gears with control columns are chiefly used for the individual drives of lathes. There are two reversing rollers on the control column for the driving belts. One of these is mounted excentrically and allows of slackening the belt by a single hand movement when the work is stopped momentarily and when it is not considered desirable to stop the motor. The gear can either be secured on the foundation or to the upright of the lathe. By means of a suitable arrangement of the operating rod connected to the motor switchbox, forward or reverse drive is switched in or reversed.

The great advantage of the designs described for geared motors and gears for motors is, on the one hand, the possibility of being able to adjust to every speed which may be required in practice and, on the other hand, the economical qualities of the drive, the exceptionally convenient and compact layout and the great reliability, even under the severest continuous working conditions.

If that part of the total cost of the plant which is required for the reduction gearing may often appear high, it must be remembered that the generation of big torques, inherent to gearing down to low speeds, naturally calls for the utilization of high-grade material and first-class manufacturing work. Electric motors of low output with speeds below about 500 r.p.m. are, usually, bigger and more expensive than the geared motors built for the same conditions. For this reason, it is not a paying proposition to build these slow-running motors. At the same time, it must be remembered that the earlier types of clumsy reduction gears with their numerous wheels, bearings and belts were much dearer to purchase and still more so to run than are modern geared motors with precision-cut teeth, which are well lubri-

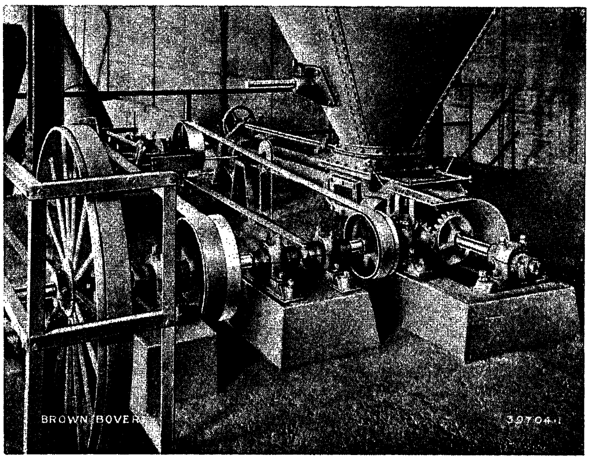


Fig. 14. — Coal screw extractor with old transmission shafting and mechanical speed-regulating control.

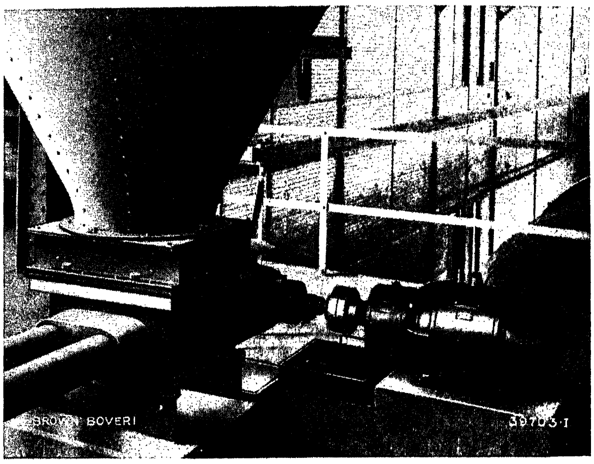


Fig. 15. — Coal screw extractor with variable-speed D.C. geared-motor drive.

cated and run in roller bearings; these are a source of only 2 to 4 % losses at full load.

Figs. 13 to 15 illustrate how advantageously driving conditions have been influenced by geared motors. Fig. 13 shows a cellulose dewatering machine which was partly equipped with sectional motor drive through variable speed D. C. geared motors. The complete elimination of heavy transmission elements made the whole machine easier to supervise and the different parts more accessible, this apart from the advantages accruing to the working conditions proper due to the replacement of belts by reduction gears combined with the perfected electric control.

The two last illustrations are intended to show the progress made in geared-motor design by a comparison of former and present-day types. Fig. 14 shows a coal screw extractor used for a rotary furnace plant in a cement mill driven by transmission shafting (not shown) through a mechanical speed-regulating device, shown in the background. Fig. 15 shows another plant of same mill, but after it had been made over for individual electric drive by a D. C. geared motor. It will be noted how simple the straight drive by the geared motor coupled to the screw is, which can be switched in and cut out and speed-regulated, exactly and with ease, from the furnace operator's post.

(MS 537) *S. Hopferwieser. (Mo.)*

RAILWAY PLANTS IN WHICH ONLY ONE MUTATOR IS USED FOR POWER SUPPLY AND FOR RECUPERATION.

Decimal index 621.331 : 621.314.652.

RAILWAY plants have already been described in which mutators are made use of to recuperate the power generated by braking trains on down gradients. However, there were, always, several mutator units in the plants in question, of which one or more were used solely as A.C.-D.C. mutators to supply the contact wire and one mutator as a power recuperator, that is as a D.C.-A.C. mutator. A short description is given, here, of a new application of the mutator to railway plants, which has attained a stage of complete development, to-day.

At the present time, there are three Brown Boveri mutators:— I, II and III, mounted in a substation supplying one of the electrified line sections A B C D (see Fig. 1) of the Italian State Railways, of which two units, I and II, are only connected for A.C.-D.C. operation, while III usually works on D.C.-A.C. service. However, if the load current of mutators I and II, working on A.C.-D.C. service, or, respectively, I or II, exceeds a certain value — as, for example, the rated figure — a current relay intervenes to change over mutator III to A.C.-D.C. service, as well, so that it shares in supplying the contact wire. In this case, the current relay is designed as a time relay, so that the limit current mentioned can flow, to begin with, for a determined time, which is set for, before the relay acts and carries out the change-over of mutator III. If now, but subsequently, the current per mutator drops below a given value, which can be set to, the current relay mentioned switches over mutator III again to D.C.-A.C. service, but this time without a time lag, so that the mutator is all ready for duty if there should arise the occasion for brake-power recuperation.

If mutator III is in D.C.-A.C. connection, it takes, continuously, a certain, low circulation current from the other mutators, as a consequence of its voltage characteristic, this current being reduced to a very low figure by means of a choke coil in series. It seems hardly necessary to mention that this type of service of the substation is no longer a problem, to-day, and, therefore, that no unpleasant surprises followed the putting into service of the said plant.

It should be added, further, that on account of the numerous trains running on this line section, the power recuperated by braking on the down gradient is, practically, entirely consumed by the other trains.

The problem of a plant with a single mutator on a small railway system is an interesting one, as the mutator must take over either function:— power supply or power recuperation, automatically and according to requirements. In this field, Brown Boveri has carried out tests on their own test bed in Baden in which a D.C. machine coupled to a synchronous motor takes the place of the locomotive, the voltage across the terminals of the D.C. machine being raised or lowered, as happens on a locomotive according to whether it runs on a down or an up-gradient. The mutator connections are changed over in function of the D.C. voltage or an equivalent thereof. The said changing over for one or the other service takes place, here, without any time lag.

In railway plants, however, conditions are not quite as described here, because when the locomotive goes over from motor drive to generator drive and vice versa, a change of connections must be carried out on it, during which the locomotive is cut off from the contact wire, for a short time.

It was, thus, very interesting, indeed, to get an opportunity of seeing how the equipment would work on a real railway system.

It should be said, here, that the object of the tests was not to find out if the above plant, built for heavy full-gauge railway traffic, could be used with a single mutator but the object was to discover if it was really practical to equip small railway system, having relatively light traffic, with a single mutator designed to supply all the power needed. The condition was laid down that, for this kind of operation, the motors of the locomotive should be excited by a small converter set, mounted on the locomotive during the power-recuperation periods.

Brown Boveri delivered the extra material necessary to carry out these tests. The line profile utilized is shown in Fig. 1. It is between stations A and E and is 17·5 km long with a difference of altitude of 182 m. Station C with the substation is at the highest point on the line section. The contact-wire voltage is 3200 V. As traffic is very heavy, it was necessary to connect up the mutator in question

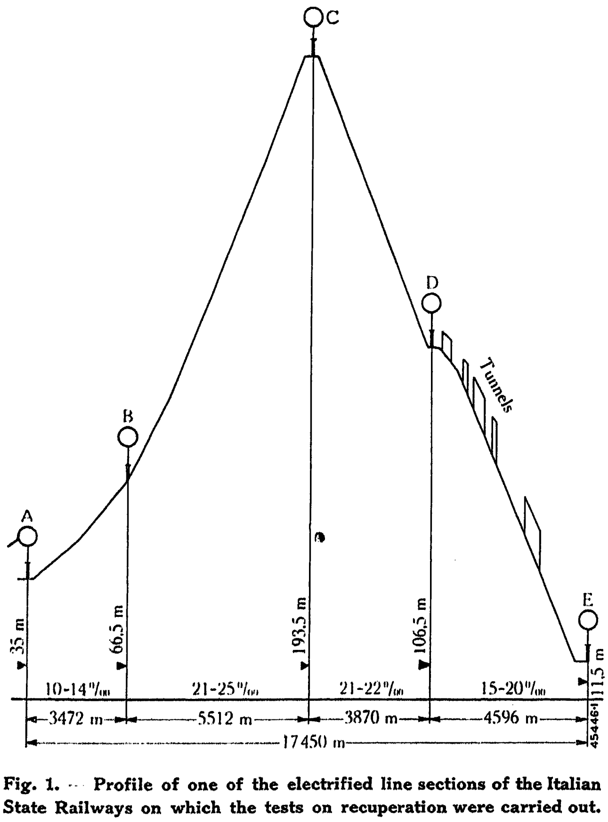


Fig. 1. — **Profile of one of the electrified line sections of the Italian State Railways on which the tests on recuperation were carried out.**

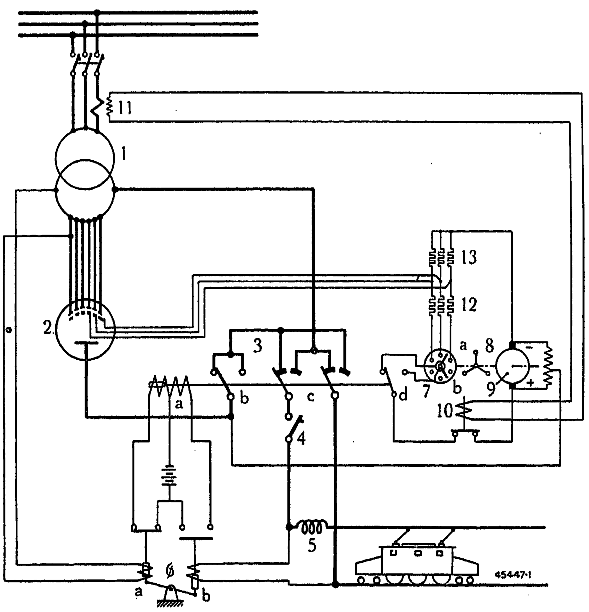


Fig. 2. — **Fundamental diagram of connections of the plant.**

1. Mutator transformer.
2. Mutator.
3. Change-over switch.
3a. Drive of switch.
3b. Sparking switch.
3c. Change-over contact.
3d. Change-over switch of grid.
4. Reverse current and over-current high-speed breaker.
5. Choke coil of wave filter.
6. Differential voltage relay.
7. Grid control distributor.
7a. Brush for A.C.-D.C. service.
7b. Brush for D.C.-A.C. service.
8. Synchronous motor.
9. D.C. machine for grid voltage.
10. Grid relay.
11. Current transformer for grid relay.
12. 13. Grid resistances.

(mutator III) alone on a down gradient (which, however, requires power input at certain points), in order to carry out the test in the desired way. Fig. 2 shows the fundamental diagram of connections. The method of operation is the following:— if the ampere-turns of coil a are preponderant, on differential relay 6, as occurs when the D.C. voltage is low, the magnetic armature is drawn up, which closes the contacts and the change-over switch is displaced towards the left in A.C.-D.C. working sense. If, now, the D.C. voltage rises, the magnetic armature b is drawn up and the change-over switch moves over to the D.C.-A.C. service position. The sparking switch b of Pos. 3 is always open when the change-over contacts c are opening or closing or are opened, so that they never switch under current. When the change-over switch acts, the ignition angle of the grid is always displaced by the desired amount and the necessary interlocking of the connections are carried out. If a back-fire occurs in A.C.-D.C. service, or if there is a passing short circuit on the line, the short-circuit current operates the grid relay 10 through the agency of current transformer 11. In either case, the mutator is extinguished by the grid and the trouble suppressed in less than a cycle.

If, now, a train is on the down gradient, for example, from station C to station E, it starts up in the ordinary traction connection. Before it attains the normal travelling speed on the down gradient, the locomotive driver disconnects the locomotive from the contact wire and carries out the recuperative connection, in doing which he connects the whole resistance in series with the motors and their (separate) excitation. The motor of the excitation converter set is connected continuously to the contact wire. After this, the locomotive is connected up again to the contact wire. The locomotive driver ascertains, from consulting the ammeter, that the locomotive is still consuming current and he increases the excitation until the motor current is, practically, zero, upon which he switches out the resistance in series with the motors down to the low protective resistance. Under the succeeding and automatic acceleration of the train on the down gradient, the locomotive voltage increases above the no-load voltage of the mutator, which causes it to be switched over to D.C.-A.C. service and it begins to consume braking power from the locomotive. The speed of the train is regulated by the driver, from now, by means of the excitation. Before the train runs into station D, the locomotive driver disconnects the locomotive from the contact wire and reconnects the locomotive for traction driving; this makes the voltage on the contact wire zero. The mutator is immediately switched over to A.C.-D.C. service. The train is now braked down by means of the mechanical brake and brought to a stop in the station. Exactly the same procedure is gone through between stations D and E, namely:— starting, recuperating, cutting out, braking down to a stop. Processes of this kind are recorded by means of recording voltmeters and ammeters in station C.

Figs. 3—5 reproduce some typical diagrams. The diagrams shown in Fig. 3 are of the down-gradient trip of a 440-t train from C to E. From a to b shunting is being carried out in the station. At point c, the train starts in traction connection; at d, the locomotive is switched over to recuperation; between d and e, the train is running downhill and is recuperating, during which, however, the mechanical brakes are applied, three times, so strongly that the D.C. voltage delivered by the locomotive drops below the no-load voltage of the mutator and the mutator, therefore, is switched over to A.C.-D.C. operation on each of these occasions. Between e and f, the train is in the D station, at f it starts out of the station under traction connection; at g the locomotive is switched over to recuperation. From g to h the train is on the down gradient between D and E, the peak value of 380 A at 3460 V being attained, corresponding to a 1320-kW output recuperated.

The diagrams corresponding to Fig. 4 show the trip of a 500-t train from C to E. Between a and b the train draws out of C station, in traction connection; at b, the locomotive is switched over to recuperation; from b to c there is recuperative running between stations C and D; from c to d there is a stop in the D station; d is the drawing out of the D station in traction connection and, at e, there is switching over of the locomotive to recuperation; between e and f there is recuperation between the D and E stations.

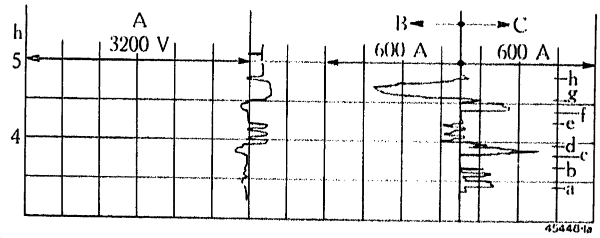


Fig. 3. — Current and voltage diagram for down-gradient run of a 440-t train from station C to E.

A. D.C. voltage.
B. Amperes D.C. during D.C.-A.C. service.
C. „ D.C. during A.C.-D.C. service.
Speed of paper strip 120 mm/h.

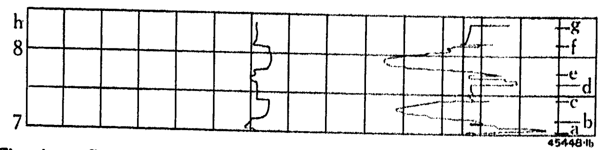


Fig. 4. — Current and voltage diagram for down-gradient run of a 500-t train from station C to E.

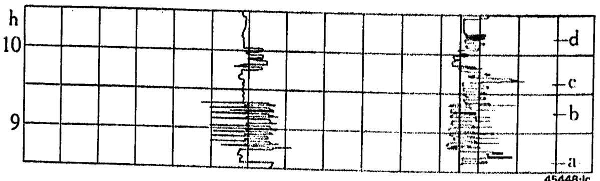


Fig. 5. — Current and voltage diagram for down-gradient run of a 90-t locomotive from station C to E, with simultaneous shunting service carried out by a locomotive in station E.

The service conditions described are met with when there is only one train on the line section. Matters change, immediately, when there is a second or several trains on the line, at the same time. In order to represent cases of this kind, while a locomotive of 90 t was on the down gradient from C to E, a second 90-t locomotive was caused to start and stop continuously in the E station, which is shown in the diagram of Fig. 5. In this test, the starting power consumed by the shunting locomotive at each start was always greater than the brake power regenerated by the locomotive on the down gradient. At point a, the locomotive draws out of C station in traction connection after which it is switched over to recuperation. From a to b, the locomotive on the down gradient is between stations C and D. Between b and c, the locomotive is stopped in D station, at which period, the diagram shows clearly the power peaks consumed by the shunting locomotive. At c, the locomotive, in traction connection, draws out of D station and is, then, switched over to recuperation. Between c and d, the locomotive is on the line section between stations D and E. On the line section between C and E, the change-over switch of the mutator was automatically operated twenty-two times. The considerable voltage fluctuations seen in the diagram are caused by the power consumption of the shunting locomotive at starting being, always, bigger than the braking power recuperated from the locomotive on the down gradient. It is only after the change-over switch of the mutator has been changed to A.C.-D.C. service that the full voltage appears on the contact wire again.

A great number of tests such as are shown, in principle, in Figs. 3—5 were carried out on site and were always satisfactory after a certain number of slight failings in the equipment had been remedied. The results should be sufficient to show that a single mutator can be used on small railway plants for power supply and power recuperation.

It should be added that the mutator transformer was in fork connection and that the tests were carried out without wave filter. Nevertheless, it was necessary to insert, continuously, a discharge resistance for some amperes between contact wire and ground, in order to prevent a rise of the contact-wire voltage to the peak value of the phase voltage, when the mutator is under no load. This would have given rise to troublesome change-over processes on the mutator. This is because the contact wire can be assimulated to a condenser. In practical cases, of course, this discharge resistance could be replaced by a useful consumer or else a relay could be used which would only switch it in when the station current fell to a determined minimum value.

It should, also, be noted that, in changing over from one service to the other, there is practically no current to be ruptured. In the change-over from A.C.-D.C. to D.C.-A.C. service there is no current to switch at all and in changing from D.C.-A.C. to A.C.-D.C. there is only a current to switch when there is another train on the line section consuming more power than that restituted by the one on the down gradient. Therefore, the mutator change-over switch 3, shown in Fig. 2, is only equipped with a sparking switch of corresponding capacity. There is, however, a high-speed breaker (for the case of back-fires or short circuits) (Pos. 4) in series with the change-over switch.

(MS 550) *S. Widmer. (Mo.)*

BROWN BOVERI HEAVY-CURRENT MUTATORS IN ELECTROLYTIC PLANTS.

Decimal index 621.314.65:621.357.1.

ONE of the mutator plants of highest output at present operating in the chemical industry is that of the Consolidated Mining and Smelting Company of Canada situated in British Columbia. This mutator plant has a total output, to-day, of 53,500 kW of which 46,800 kW are delivered by Brown Boveri mutators and 6700 kW by mutators built by other firms. The first mutator plant installed, that of Tadanac, shown in Fig. 1, comprises three sets each of 10,000 A at 560 V D.C. and, thus, attains a total output of 16,800 kW. This plant has been running since the year 1929, producing electrolytic zinc. The mutators are grid-controlled and also equipped with the Brown Boveri short-circuit protection against external short circuits and back-fires. There are high-speed breakers on the D.C. side to ensure the rapid rupturing of reverse currents.

As early as the year 1931, Brown Boveri had occasion to deliver to the Consolidated Mining and Smelting Co. two more heavy-current mutators each for 10,000 A at 670 V D.C. for the Warfield I plant, shown in Fig. 2. These mutators are used to supply large batteries of electrolytic cells to generate

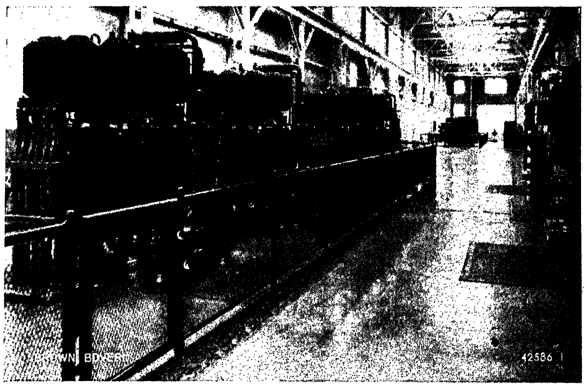


Fig. 1. — First mutator plant of the Consolidated Mining and Smelting Co. of the year 1929. The Tadanac Plant with three Brown Boveri mutator sets, each of 10,000 A at 560 V D.C.

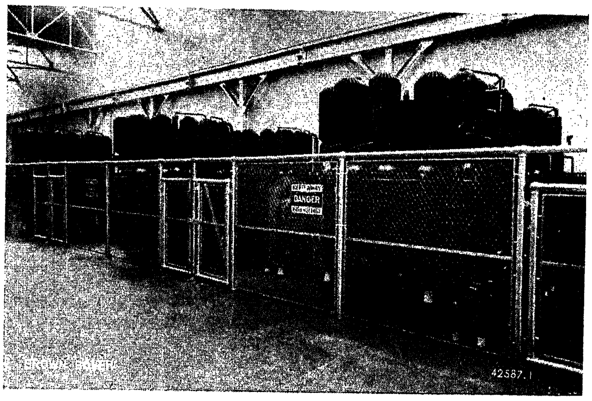


Fig. 2. — Warfield I mutator plant, of the year 1931, with two Brown Boveri mutator sets each of 10,000 A at 670 V D.C. In the background, part of Warfield II plant, with two Brown Boveri mutator sets, each of 8300 kW.

hydrogen which is then used to make artificial fertilizer products such as ammonium sulphate, ammonium phosphate, ammonium super-phosphate. These mutators are also, grid-controlled and equipped with protection against external short circuits and back-fires by means of controlled grids. High-speed D. C. circuit breakers are inserted on every cathode lead for cutting out the very heavy reverse currents which may flow from the cells if a short circuit occurs and may attain 30,000 A.

There is a more detailed description of these plants in the October number of The Brown Boveri Review 1930 and in the April number of 1936.

Owing to the most satisfactory service results reached with the heavy-current mutators, Brown Boveri received an order, in 1935, for two further mutator sets, each of 10,000 A for the enlargement of the plant, the D. C. voltage being 830 V in this case, which corresponds to a total output of 16,600 kW for the two sets.

Despite the great distance between Switzerland and British Columbia, corresponding to at least 1 to 2 months for transport from works to erection site, this plant was put to work within seven months from the time the order was placed, the whole equipment having been built in the Brown Boveri workshops in the exceptionally short time of 4 $^1/_2$ months.

This part of the plant (Warfield II), put to work as early as February 1936, is shown in the illustration on the cover of this number. The plant proper with two Brown Boveri mutator sets, 10,000 A, 830 V, is seen in the foreground. The principle connections of this plant are shown in the diagram of Fig. 3. As is seen, there are oil circuit breakers on the primary side, as shown in Fig. 4. These comprise, each, three single-pole Brown Boveri oil circuit breakers for 1·5 million kVA rupturing capacity at 60,000 V primary voltage.

The D. C. voltage can be regulated over the 740—830-V range by means of regulating transformers inserted on the 60,000-V side; these are shown in Fig. 5. The transformers of the first plants were

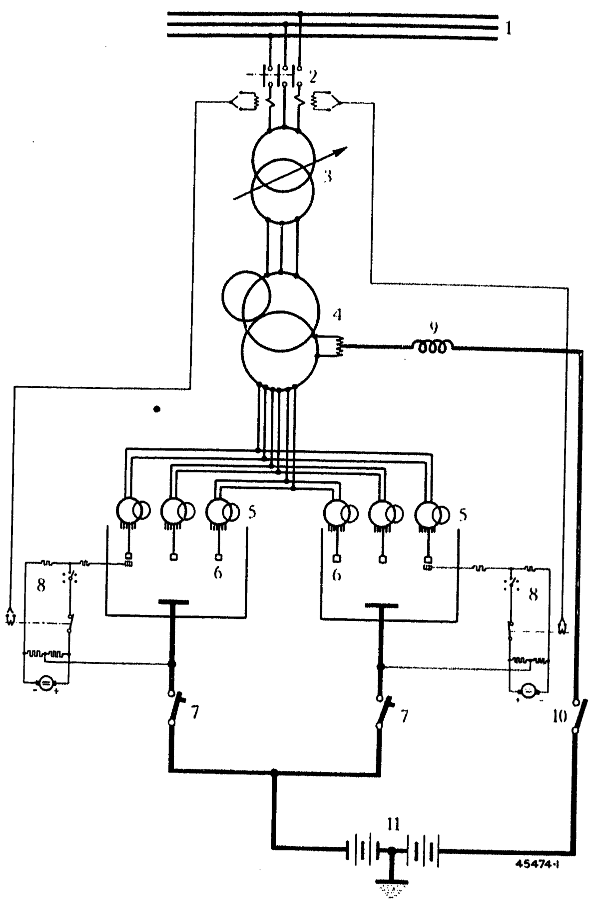


Fig. 3. — Fundamental diagram of connections of the mutator sets in the Warfield II plant.

delta-connected on the primary side while those of this latest plant are star-connected on the primary side, with the object of suppressing the 5 th, 7 th, 17 th, 19 th, etc. harmonic currents; this arrangement gives the advantages of twelve-phase operation while retaining that of simple, rugged design inherent to six-phase transformer construction. There is a tertiary transformer winding connected in delta for the sup-

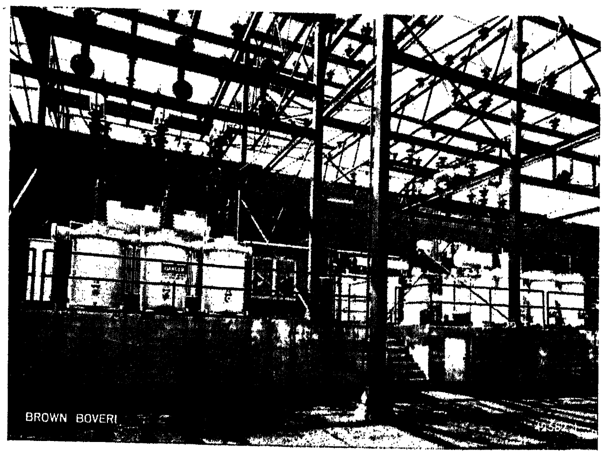


Fig. 4. — Two Brown Boveri oil circuit breaker sets of the Warfield II outdoor station, each for a rupturing capacity of 1·5 million kVA, supply voltage 60,000 V.

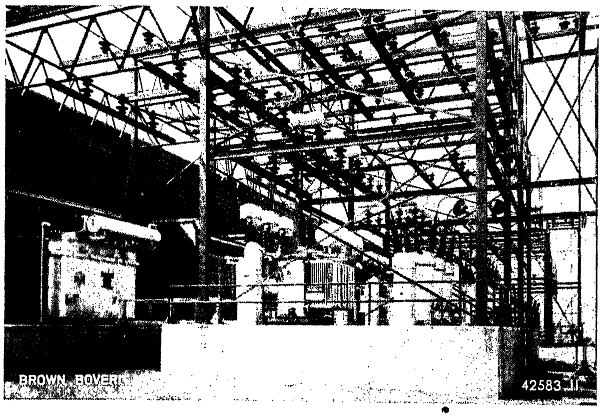


Fig. 5. — Warfield II outdoor station. Each mutator set has an oil circuit breaker set, a regulating transformer and a mutator-supply transformer.

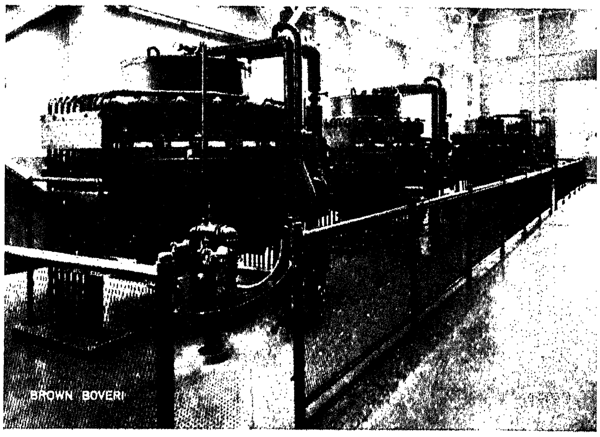


Fig. 6. — Brown Boveri mutator sets of the Warfield II plant, each of 10,000 A, 830 V D.C.

pression of the 3rd harmonic, a necessary addition on account of the star connection of the transformer on the primary side. Thanks to the use of controlled grids, it was possible to attain great service reliability by suitable design of the interior organs of the mutator chamber proper, this while avoiding too much blocking effect of the valve. This allows of perfect ignition under all service conditions, whether the chamber is very hot or is cold; thus, the mutators can be put to work at any moment without any special preheating of the mutator cylinder or of the anodes, themselves. Each pair of mutators is connected to one transformer, supplied at 60,000 V on the primary side; on the secondary side, the six phases are connected through anode choke coils to the anodes of the two mutators. This transformer, also shown clearly in Fig. 5, contains the interphase reactor and anode choke coils in its tank and is oil-cooled, the oil being circulated through a water-cooled counter-flow cooler.

Fig. 5 shows, very clearly, the layout of the outdoor station for the two mutator sets, each comprising an oil circuit breaker, regulating transformer and main transformer. The two mutator sets of the Warfield II plant are shown in Fig. 6. The mutators have indirect fresh-water cooling and are grid-controlled.

The controlled grids fulfil two purposes, here:— When the voltage is being raised, that is, when cells are switched in again, it is possible to regulate the voltage smoothly upwards by means of the controlled grids, thus avoiding any current surges in the electrolytic cells, further, in continuous service, the D.C. voltage can be regulated and, in case of a short circuit or of a back-fire, both mutators are extinguished immediately by the action of the Brown Boveri short-circuit protective equipment, the fundamental elements of which are shown in Fig. 3. The positive grid voltage is cut off immediately and a negative potential impressed on all the grids when a short circuit occurs, through the action of a quick-acting instantaneous-tripping grid relay, controlled from the primary circuit; and as, the reverse-current from the cell batteries is cut out by the high-speed D. C. circuit breakers, at the same time, the grids are able to extinguish a short circuit within one cycle, so that the whole apparatus is completely and simultaneously protected. All circuit breakers as well as the whole grid-control apparatus of both mutators are actuated and controlled from a common switchboard. Further, the more important functions of the plant are supervised automatically. Thus, alarm signals notify at once that abnormal conditions prevail as, for example, too high mutator, or transformer temperature, too high gas pressure in the mutator, trouble on the vacuum pump or grid apparatus.

In case of a short circuit, the oil circuit breaker is opened by the action of primary over-current relays and, in case of failure of the primary supply, by a low-voltage relay; in the case of trouble on the grid control, it is opened by the action of an excitation relay.

The high-speed D. C. breakers trip automatically on overload currents and, in the case of back-fires, on reverse currents. Thus, the most important functions of the plant are supervised, automatically, which allows of reducing the number of operators to a minimum, despite the considerable area covered by the plant. The whole plant is designed according to the most modern experience and investigations, and will be a standard design for future plants of the same kind.

It should be mentioned that this mutator plant is already being increased by the addition of another mutator set of 8300 kW, 10,000 A, 830 V, ordered again from Brown Boveri at the beginning of this year. The new plant will be, practically, identical in design to that of Warfield II.

Thus, the very successful introduction of heavy-current mutators to the industrial electrolytic field has, quickly, caused the rotary converter to loose the position it formerly held.

There can be no doubt that the grid-controlled heavy-current mutator in its latest and perfected design is superior to any other type of converter, both from the economical point of view and on account of its great technical superiority, and its future in the electrolytic field seems assured.

(MS 544) *A. Leuthold. (Mo.)*

NOTES.

The Stöckalp-Melchsee-Frutt Aerial Cable Railway.

Decimal index 625.52 (494).

THE Stöckalp-Melchsee-Frutt Aerial Cable Railway in Central Switzerland, mentioned briefly in The Brown Boveri Review of July, 1936, page 194, incorporates some interesting characteristics which are here described.

The ropeway is 3500 m long and is the longest of its kind in Switzerland, up to the present time. The difference of altitude between the two stations is 826 m and, at the upper end, there is a slight decline before the terminal station. There are two cabins, each holding four passengers, seated, running in shuttle service on the two carrying cables of 32 mm diameter spaced 4 m from one another. These cables have, each, a rupturing strength of 70 t. The cabin is suspended from an eight-wheel frame and the travelling speed is 4 m/s. The driving gear is in the lower station and consists, mainly, of a two-groove driving pulley and a single-groove disc round which the traction cable passes. The main driving motor is a three-phase induction motor with a rated output of 40 kW at 965 r.p.m., 380 V, 50 cycles. A centrifugal switch is built on to the driving motor which acts when the travelling speed exceeds the rated figure by 20 % and causes the railway to be stopped by tripping the circuit breaker of the motor and freeing the gravity brake. The motor is started and the travelling speed of the cabins regulated by means of a nine-step change-over controller. The two mechanical braking devices consist of a hand brake built on to the driving pulley and a gravity brake acting on the driving shaft, which is regulated from the controller electrically. The second brake is actuated by the newly-developed electro-hydraulic thruster brought out by Brown Boveri as a substitute for big brake releasing electro-magnets or the motor type of brake releaser. This thruster has an adjustable drop-weight damping characteristic which allows of smooth braking down of the cabins, when the brakes are applied, whatever the travelling speed. This braking device is also used as a service brake so that the speed at entering the stations can be regulated by moving the controller, alone. It also works automatically if current from the supply system fails, if the highest allowable speed is exceeded and if the cabins run over their proper stopping points; it is, therefore, an important safety feature of the railway.

Among other precautionary devices, mention should be made of an auxiliary drive with petrol engine, also of an automatic grip brake built into the supporting frame of the cabin and operating automatically so as to close if the traction cable should break; catch-hooks on the supporting frame of the cabin so that, if the wheels of the latter should jump the supporting cable, it is impossible for the cab to fall; auxiliary cabins and tackle to allow of lowering passengers, if the cabins were to be immobilized between the two stations. There is a telephone equipment, with wires carried on the towers, which allows of communication between stations and cabins. The Eisen und Stahlwerke Oehler & Co. A.-G. in Aarau, Switzerland, acted as general contractors for this ropeway, which is used both for passengers and goods. The electrical equipment is by Brown, Boveri & Co., Ltd., Baden, Switzerland.

Despite, or rather, because of its simplicity, this aerial cable railway has proved to be very suitable for all requirements and to be thoroughly reliable.

(MS 529) *E. Hugentobler. (Mo.)*

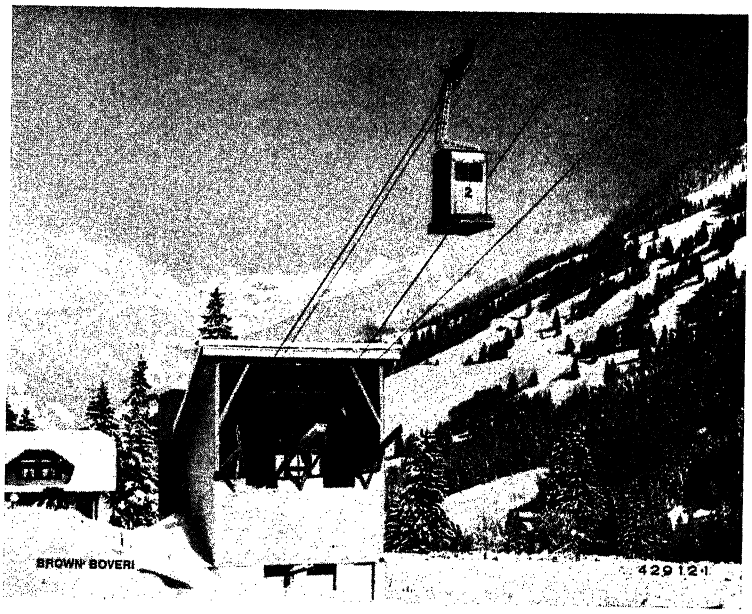


Fig. 1. – Driving station at Stöckalp of the Aerial Cable Railway Stöckalp-Melchsee-Frutt.

2-Do-2 express locomotives for the French State Railways (Chemins de fer de l'Etat).

Decimal index 621.335.2. (45).

THE electrification of the Paris-Le Mans line section of the Chemins de fer de l'Etat (France) was decided on, at the beginning of 1935, the work coming within the scope of the national programme of public work. The management of the railways entrusted the Compagnie Electro-Mécanique, Paris as general contractors with the delivery of 23 electric locomotives for express service on the said line section. These machines are designed for a one-hour rating of 4200 H. P. at wheel tread. They are supplied with D. C. current from the contact wire, at 1500 V. Each locomotive has four motors and the travelling speed under one-hour load rating attains 69·5 km/h with a maximum of 130 km/h. In exceptional cases, it should be possible to travel at 150 km/h. The diameter of the driving wheels is 1750 mm and that of the carrying wheels 970 mm; the total weel base is 14,400 mm. The total weight attains 129 t of which 56 t are for the electrical equipment and 71·5 t are for the mechanical part; the rest of the equipment (oil, tools, sand) taking about 1·5 t.

The design and characteristics of these locomotives are exactly the same as those of the units of same type delivered to the Paris-Orléans Railway, except that the present machines are not designed for power recuperation.

The mechanical part of the locomotives for the Chemins de fer de l'Etat is built by the Compagnie de Fives-Lille. All these machines for the Etat and P. O. services have Brown Boveri individual axle drive in its original form:— lodged outside the frame of the locomotive proper and combined with an inside frame, with automatic pump and gravity lubrication.

Acceptance tests were carried out in January 1937 on the first locomotive delivered, at the end of 1936, for the Chemins de fer de l'Etat. These tests took place on the Paris-Tours line section of the P. O. Railway, with trailer loads up to 800 t and maximum speeds of 130 km/h. Immediately afterwards, the Ministry for Public Works granted the permission to put this machine into service (see illustration on page 174).

As the work on the Paris-Le Mans line section is not sufficiently advanced to allow of using the locomotives on the said section, those of the 23 locomotives which are ready earlier will be utilized on the P.O.-Midi Railway system, up to a total travelling distance covered of 20,000 km per locomotive, which is the distance a locomotive must travel over before its conditional acceptance by the Chemin de fer de l'Etat.

With the completion of this series, there will be 68 locomotives of this design on French lines. The type is one which has given the greatest satisfaction as regards performance and design. *(MS 556)* *E. Schroeder. (Mo.)*

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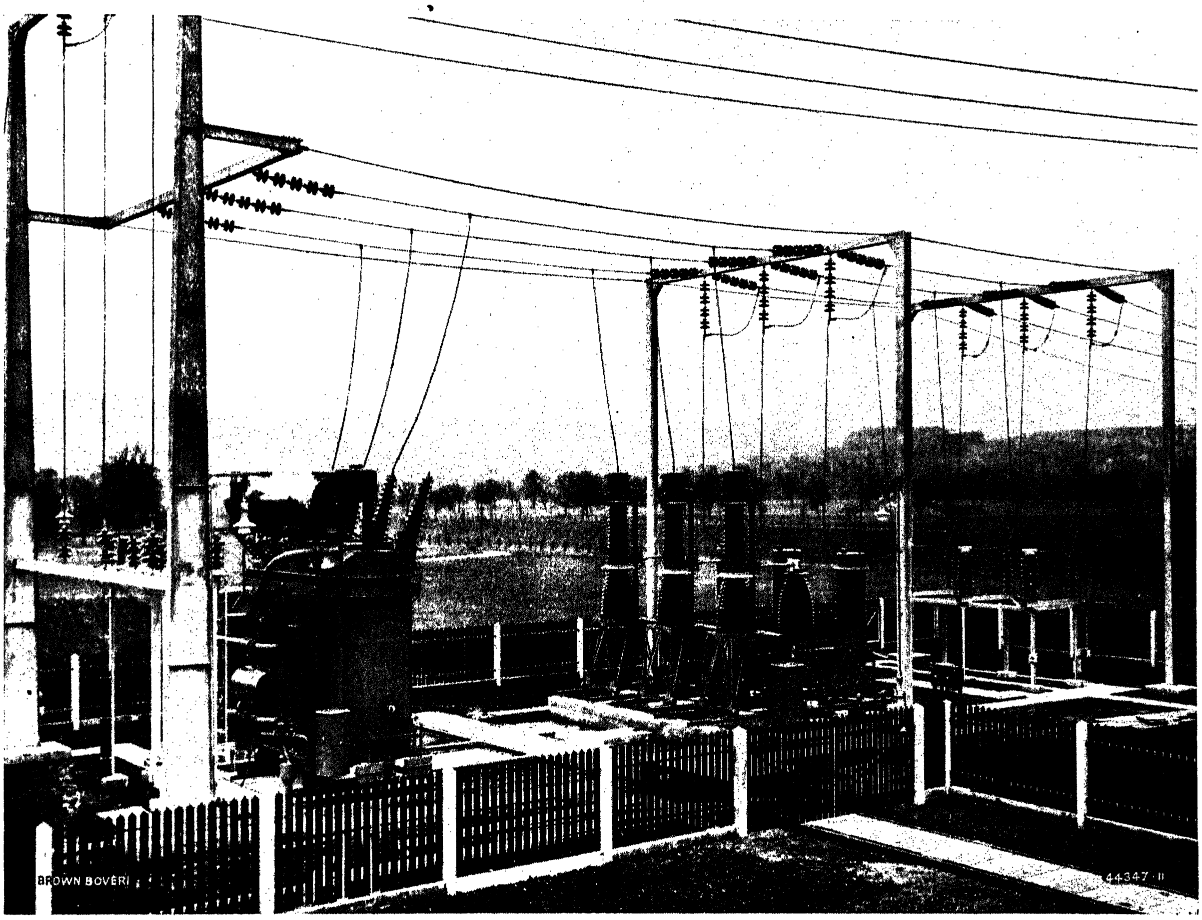

OUTDOOR STATION OF THE OLTEN-GÖSGEN POWER PLANT OF THE AARE-TESSIN A.-G., OLTEN (SWITZERLAND).

Three-phase regulating transformer 32,500 kVA with convector circuit breakers.

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Printed in Switzerland.

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

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THE ROSENKRANTZGATE STEAM POWER STATION OF THE OSLO ELECTRICITY WORKS. A VELOX PEAK-LOAD PLANT OF CONSIDERABLE OUTPUT.

Decimal index 621. 311. 22 (481).

GENERAL NOTES.

THIS interesting steam power station, the enlargement and modernization of which was entrusted to Brown Boveri, has already been mentioned in the August number of The Brown Boveri Review of 1935.

The chief duty of this plant is to cover part of the peak-load requirements of the town of Oslo, in years when the available water power is very low, the said winter-day peak load attaining the considerable figure of 100,000 kW. This plant also serves as a stand-by station, but this duty is a secondary one, only, which is rarely demanded of it.

The "plant-use factor" of thermal stations of this type is, usually, low. Experience gained in many cities shows that only about two per cent of the total number of energy units generated are required to meet the power requirements which exceed 70 % of the maximum winter peak. For the cost of power production, therefore, the first outlay on plant building is the determining factor and this, obviously, leads to the conclusion that the station must be low in cost. Its design must be simple and a maximum of useful power per cubic metre of space used must be the object striven for, or, in the case of an existing building, the object must be to utilize the available space in the best possible manner.

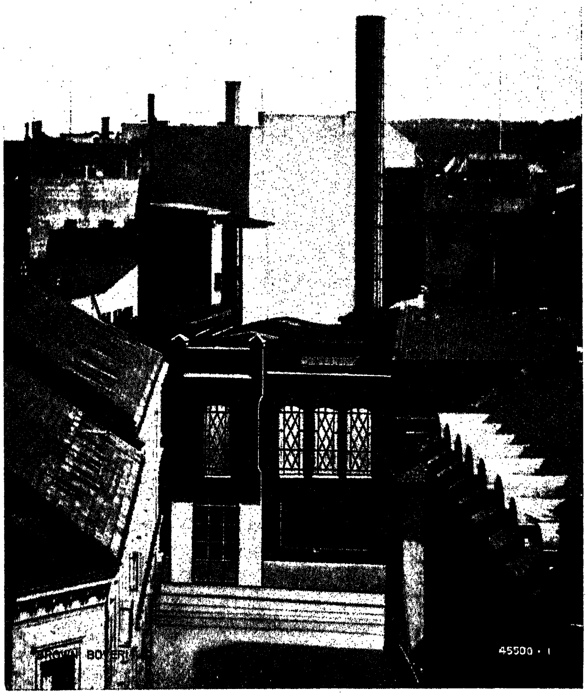


Fig. 1. — Velox power station of the Oslo Electricity Works. West façade with main portal.

No great importance is attached to high efficiency, as the number of running hours per year, usually, does not exceed some hundreds. It must not be forgotten, however, that in cases of power supply, like that of Oslo, in which the said supply practically all comes from hydraulic power stations, the gradual enlargement of the latter, a costly matter, can only take place step by step, for obvious economic reasons; thus, periods of scarcity of power occur unavoidably, during which the steam plants must deliver considerable blocks of power over long periods. Finally, account must also be taken of abnormal conditions which may arise in periods of political disturbances and during wars. Under the latter conditions, the efficiency becomes a factor of great importance, as the economical utilization of the existing fuel reserves may be a vital question. These abnormal conditions cannot, of course, be taken into account when projecting a plant. However, they are reckoned with by choosing a type of stand-by station which is economical to run, on condition that such can be put up at little extra cost.

Even when the duties to be fulfilled as a stand-by plant are of secondary importance, account is taken thereof in planning the station, so that it will be rapidly ready to take over load and that it will

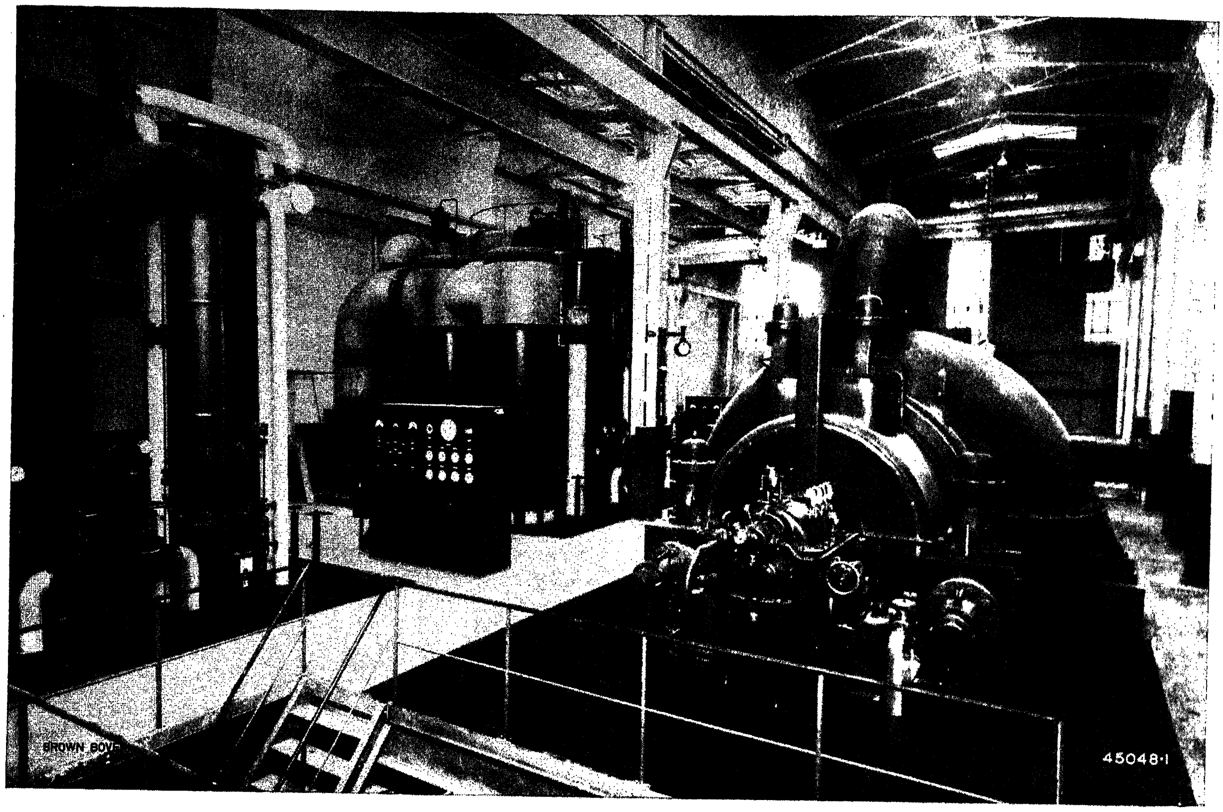


Fig. 2a. — Velox power station of the Oslo Electricity Works. View through machinery hall and Velox steam generator hall, seen from live-steam end.

possess good regulating qualities. The plant must be so laid out that only a few operators suffice to run it, which means a simply layout easy to supervise and this entails great accessibility to all vital organs; it also leads to the automatizing of those parts which allow of it by simple and inexpensive means.

A Velox power station, such as the one under consideration here, fulfils all the requirements enumerated better than any other type of plant. The size of the units put into the station under consideration is, alone, sufficient to make it a remarkable one and we think that the following description of the plant should be of general interest.

FUNDAMENTAL TECHNICAL CONDITIONS.

The old steam power station of the town which produced 12,000 kW at its terminals, is located in the middle of the city. As a result of careful investigation, the Oslo Electricity Works decided to make available the existing boiler house for the enlargement of the station. There were ten water-tube boilers in it, with a total maximum production of 110 t/h. The new requirements laid down were that there should be lodged therein, in the place of the old boilers, two turbo-sets, each for a continuous, active load of 30,000 kW with the boilers of corresponding capacity (two per machine unit), as well as the high-voltage switchgear plant, with main and station transformers and all the requisite auxiliaries etc., the whole on an area of about 24·5 × about 38 m and a total headroom of 15 m above the former service floor. The first development stage, however, only comprised the installation of one set, with its accessories.

The available floor space was very small. However when Velox steam generators are used, the solution of the problem offers no difficulties. In an article published in the ETZ entitled: "Grundsätzliche

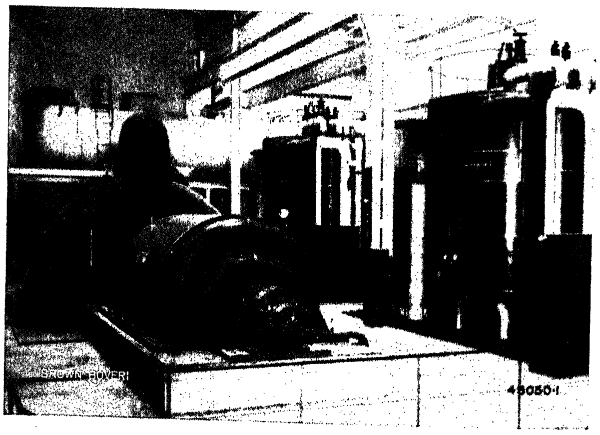


Fig. 2b. — View through machinery hall and Velox steam generator hall seen from the excitation end.

Gesichtspunkte für den Entwurf von Reserve-Dampfkraftwerken", Dr. Ing. L. Musil gives as floor-area requirements, for plants of similar size, the figure 22 m² per 1000 kW for machines and boilers together without switchgear, this, as late as the year 1933. Since then, progress has been made, in this respect. The figures relative to a Velox plant can hardly be equalled in this respect, in fact they cannot be attained at all by other boilers, if too crowded layouts are to be avoided and if the boiler plant is not to be developed vertically, according to American methods. In the case under consideration, here (Oslo), the floor-area requirements for the main machines with boilers and all auxiliaries but without switchgear is only about 10 m²/1000 kW or 45% of the figure given previously.

This steam power station is located, as already mentioned, in the centre of the town, on the Rosenkrantzgate, one of the main arteries of the quarter. As the fouling of the atmosphere by soot etc. from the chimneys of the power station gets more and more of an intolerable nuisance to the inhabitants the bigger the power station becomes, it is necessary in stations using solid fuel to have recourse to expensive and cumbersome smoke separators and to chimneys 100 m high and more. This only mitigates but does not eliminate the evil. Further, giant chimneys of this type do not add to the beauty of the town. The importance of the fly-ash plague in coal-fired steam generators is described, in detail, in a communication to "Betrieb und Forschung" of the remote-heating power plant of the Swiss Federal Institute

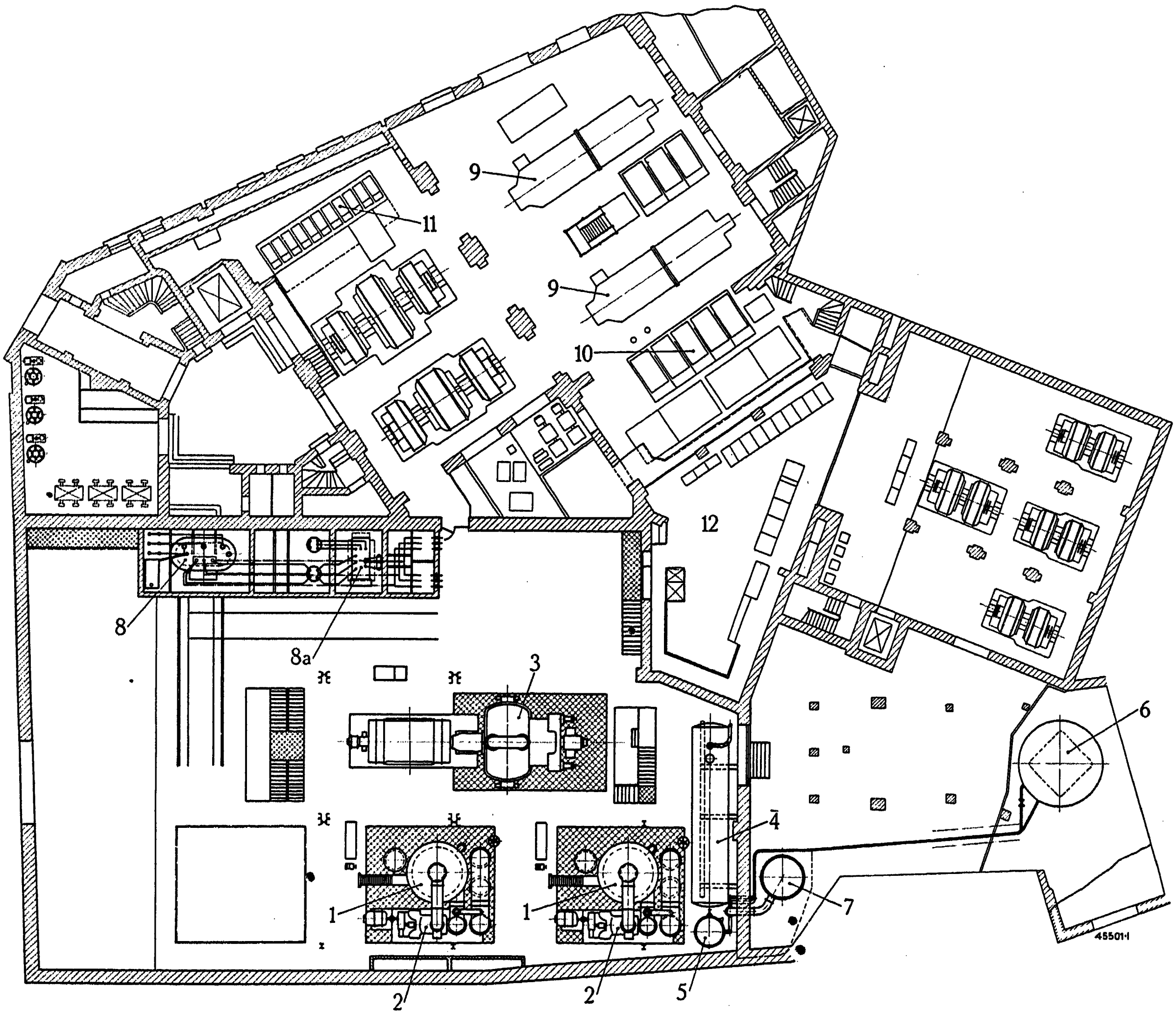


Fig. 3. — Plan of complete plant.

1. Velox steam generator.
2. Charging set.
3. Turbo-set 31,500 kW.
4. Feed-water tank.
5. Fuel starting tank.
6. Main fuel tank.
7. Stack.
8. Main transformer 35,000 kV, 6600/30 000 V.

8a. Station transformer 1600 kVA, 6600/5000/500 V.

9. Existing turbo-set 6000 kW.
10. 30-kV switchgear.
11. 5-kV switchgear.
12. Control room.

of Technology, in Zurich, under the title:— "Die messtechnische Erfassung und die Abscheidung der Russtaubmengen im Rauchgasabzug" by Prof. Dr. Bruno Bauer and Ing. F. Ruegg, Aug. 1936. Another interesting contribution to this chapter is to be found in "Power Plant Engineering", Febr. 1937:— "Efficient Fly Ash Collection", by Stanley Brown. While, in the case of plants carrying the main load, these inconveniences must often be put up with, the only good solution for peak and stand-by plants is that adopted by the Oslo Electricity Works, namely, the utilization of liquid fuels; the latter can practically, be burnt, entirely, without producing any smoke, when used in Velox steam generators, thanks to the combustion under pressure.

Apart from the space available, other factors which were fixed in advance were the cooling-water supply up to its inlet branch into the machine hall and also the connection to the system of municipal-current supply through a 30-kV cable system; these features were imposed by the existing steam power plant. The new project is, in reality, a complete plant forming an entity to itself. The new steam generators must, however, also be able to deliver steam to the two existing turbo-sets of a total of 12,000-kW terminal output and this meant putting in steam throttling and desuperheating devices, as the machines in question were built for lower steam conditions. Further, account had to be taken of the possibility of having to deliver steam to a remote-heating steam system. On the other hand, it was not necessary to design the plant as one entirely independent of external sources of electric power. The town of Oslo is supplied with current from hydraulic power stations, through several transmission lines. There is an interesting report on these conditions by H. Bärnholdt under the title:— "Re-

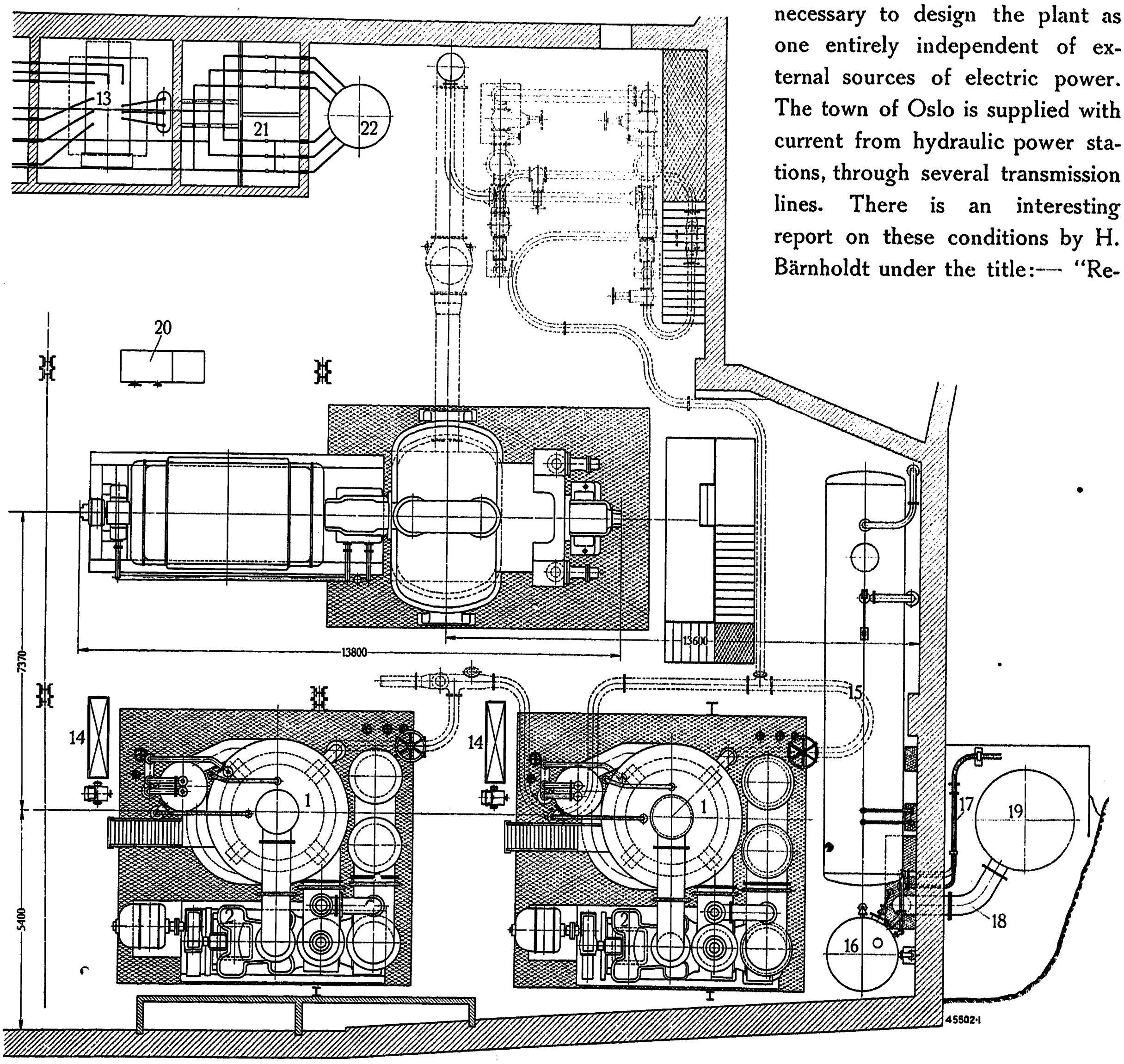


Fig. 4a. — Plan of new building.

gional Integration of Electric Utility Facilities" which was put before the World Power Conference in Washington, in 1936. The case of complete breakdown in power supply is, practically, out of the question. It is, however, possible to make the plant self-contained by adding a small station set. Fig. 3 shows the new plant as it was combined to the existing station.

GENERAL LAYOUT.

According to the layout of the former boilers (now dismantled) in two rows with a common operating bay in the centre, the old boiler house was divided up into three bays and the foundations of the boilers rested on a framework supported by piles. These conditions had to be taken into account in combining the new plant with the existing one. It was possible to lower the floor, in the central bay, to the level shown in Fig. 4b; this lowering of the floor level was limited, however, by ground-water conditions. A most advantageous layout of all parts was made by placing the machinery sets in the central bay, the steam generators in the "south" lateral bay and the electric plant in the "north" lateral bay.

There were practical technical reasons for laying the floor of the machinery hall and that of the chamber for operating the boilers at the same level. Further, no partition was put up between the three main parts of the plant:— machinery, steam generators and high-voltage plant, but the latter equipment is lodged in closed cells. The columns shown in Fig. 4 are only supports for the roof framework and the travelling cranes. The partitions, which are still called for in many countries, between the machinery hall and the boiler house must be considered

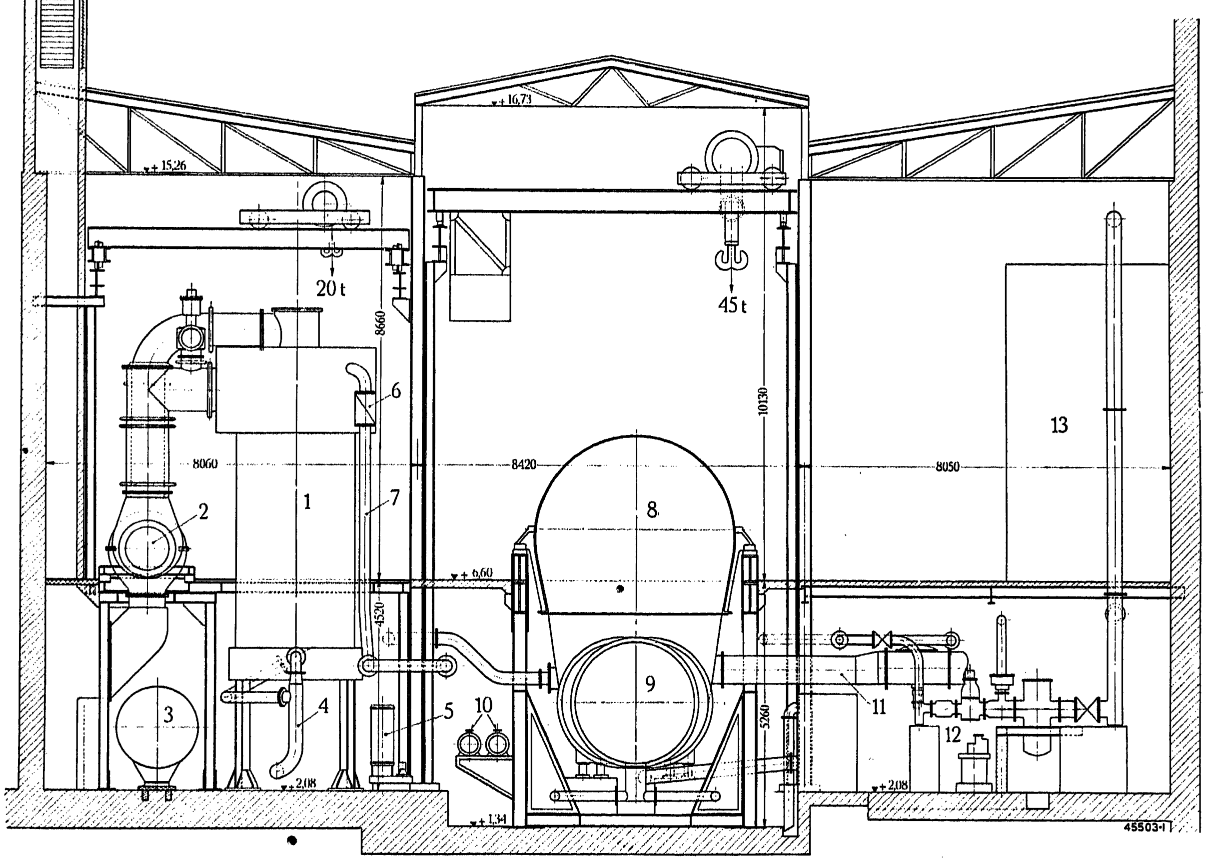
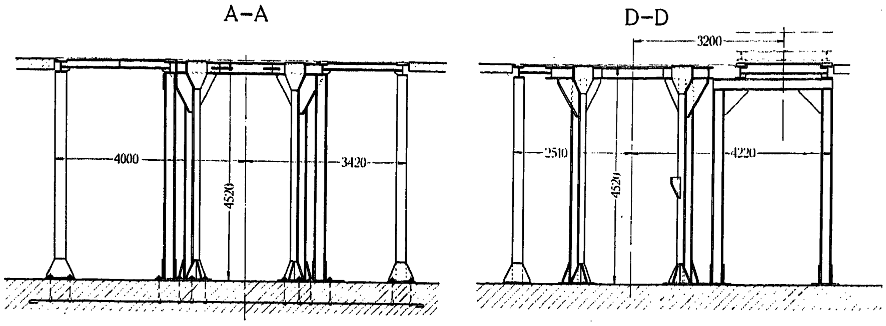


Fig. 4b. — Section of new building.

1. Velox steam generator.
2. Charging set.
3. Exhaust-gas duct.
4. Connecting pipe, circulation pump to Velox.
5. Fuel-treatment apparatus.
6. Live-steam main-stop valve on boiler.
7. Live-steam pipe.
8. Turbine (section of low-pressure part).
9. Condenser.
10. Oil-cooler of turbine.
11. Exhaust pipe with valve.
12. Steam-throttling post with steam cooler.
13. High-voltage switchgear.
14. Service and measuring panel with switch-boxes for aux. motors of the Velox plant.
15. Feed-water tank.
16. Fuel tank for starting.
17. Connection pipes between main fuel tank and starting fuel tank.
18. Exhaust pipe of safety valve from Velox to stack.
19. Stack.
20. Relay and regulator panel for turbo-generator.
21. 6600-V distribution plant (for el. boiler).
22. Electric boiler.



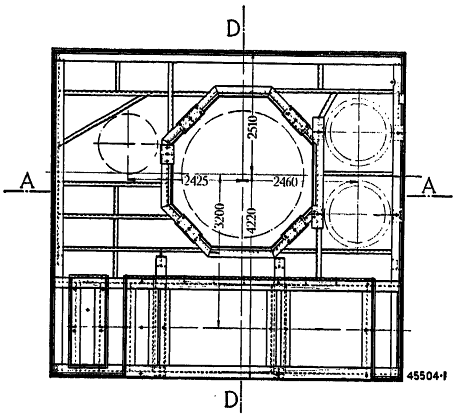


Fig. 5 a. — Iron framework of a Velox steam generator.

as obsolete. It is only justified in plants with boilers having big water chambers, but is quite unnecessary in stations in which steam is raised in generators of the Velox type. Even in the case of the rupture of tubes, there is no danger, here, for the operators as all evaporating tubes are enclosed in the combustion chamber which is made of metal which can stand up to high pressures. It is so designed that it will resist those pressures which may arise at the sudden ignition of an expanding chamber charge.

BUILDING MEASURES.

As the most important constructive measure carried out, mention should be made, apart from the removal of the old boilers and the breaking-up of the existing high chimney stack, of the lowering of the floor level in the central bay and the laying down by ramming of a carrying-pile framework for part of the foundations of the turbo-set; further, the lateral supporting walls of the building, were strengthened and the same was done to the iron supporting columns of the roof construction and travelling crane track; a new iron chimney was also put in. It is impossible to go further, here, into the building details.

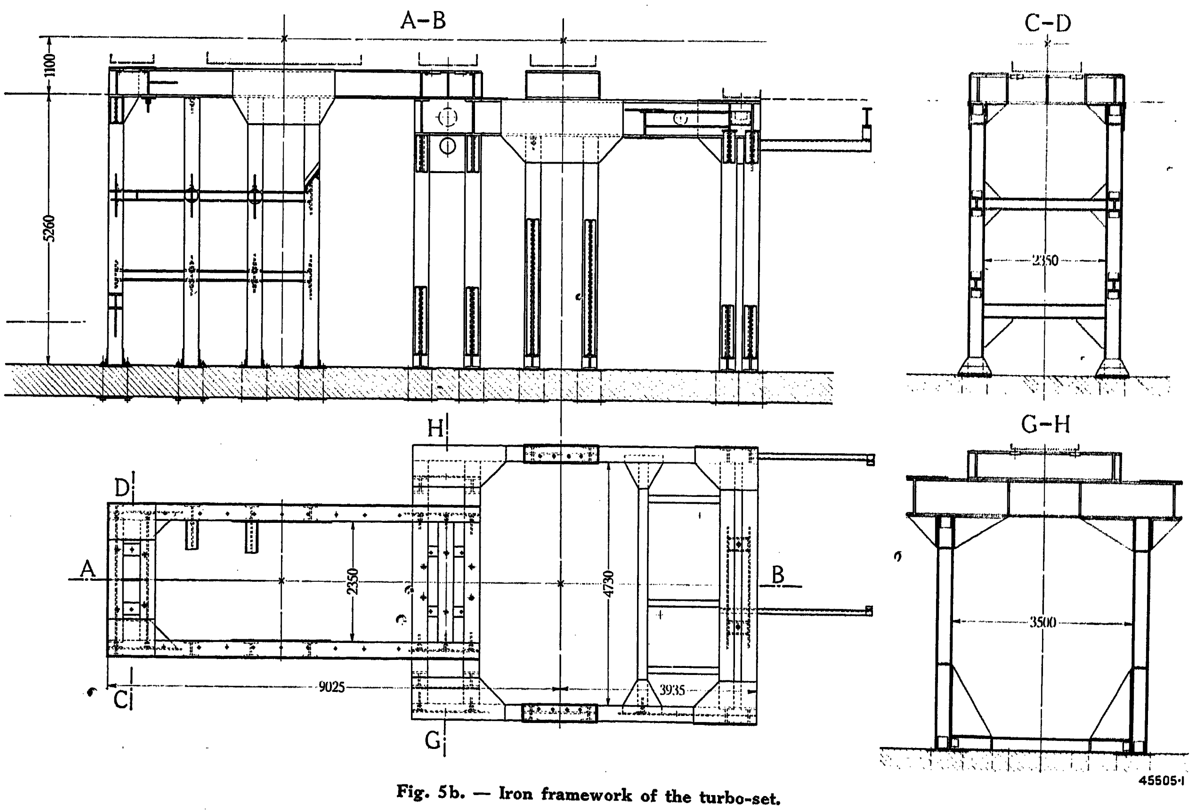


Fig. 5b. — Iron framework of the turbo-set.

The restricted available space was especially felt in the case of the condensing plant. This made it necessary to place the condensers horizontally and to use iron frameworks for the turbo-set, in order to be able to lodge a sufficiently big condenser while leaving the space desirable for the service operators to move about and get access to all requisite parts. In consequence, all the main parts of the plant are supported on iron frameworks which are so amply dimensioned that there is no danger of oscillating phenomena being set up. These supporting frameworks are formed of separate frames of welded construction, as far as possible, and bolted one to another on site. Figs. 5a and 5b show the frames for the boiler and main machinery set.

The comparison shows how simple and light the iron work is, especially in the case of the Velox steam generator, thanks to the low weight of the latter.

MAIN OPERATING DATA.

The service conditions of a steam power station are dictated by the duty it has to fulfil. It would be a decided mistake to build a peak and stand-by power house for a very high steam pressure, as was suggested in some quarters for the plant under consideration. This would not only be contrary to the requirement of low first costs (allowing for equally good material) but would also be contrary to that of instant readiness for service. Further, the layout of a high-pressure plant is never as simple as that of a low-pressure one and the starting-up time of the former is generally longer, as high pressures generally go with higher live-steam temperatures for

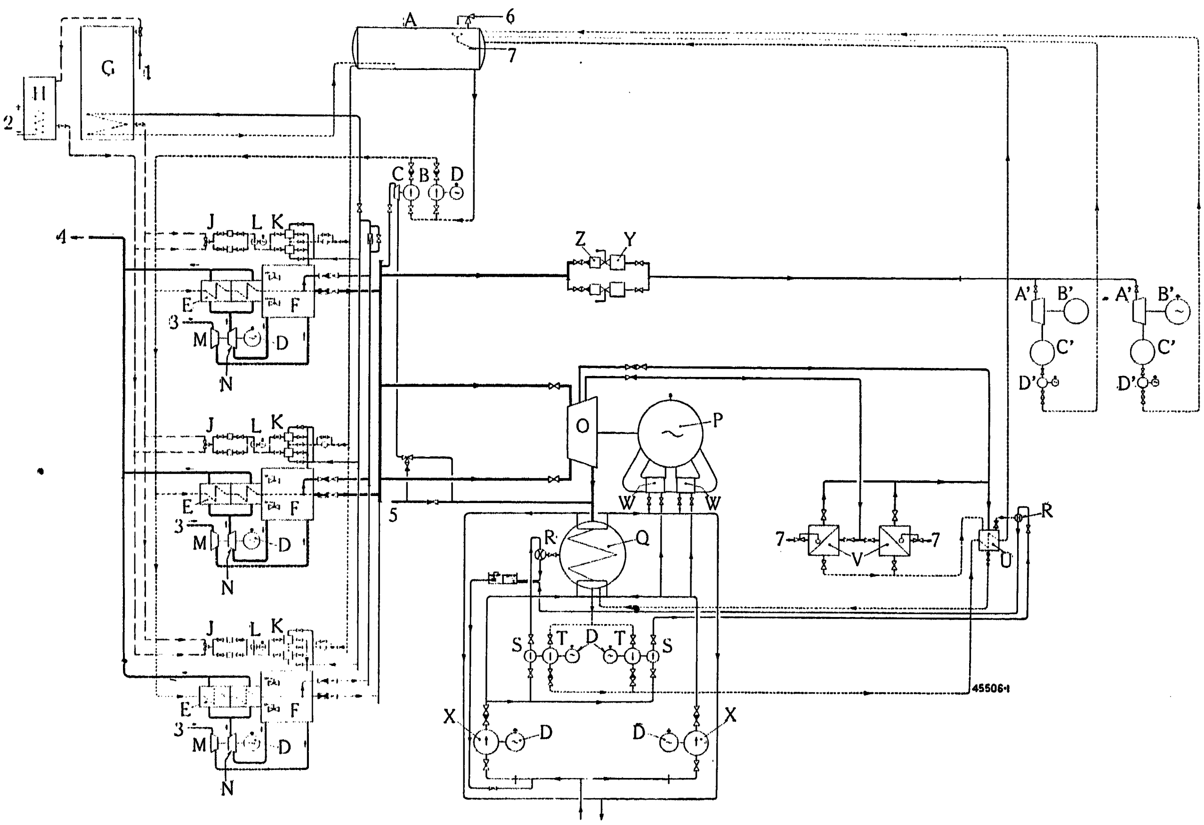


Fig. 6. — Thermal and connection diagram of the mechanical part of the plant.

A. Feed-water tank.
B. Feed-water pumps.
C. Driving turbine.
D. Motor.
E. Preheater.
F. Velox.
G. Fuel main tank.
H. Fuel starting tank.
J. Fuel filter.
K. Fuel preheater.
L. Fuel pump.
M. Compressor.
N. Gas turbine.
O. Main turbine.
P. Turbo-generator.
Q. Condenser.
R. Water-jet ejector apparatus.
S. Ejector pump.
T. Condensate pump.
U. Condensate heater.
V. Evaporator.
W. Air cooler.
X. Cooling-water pump.
Y. Hot-steam cooler.
Z. Throttle valve.

A'. Turbine
B'. Generator
C'. Condenser
D'. Condensate pump
} Two existing low-pressure sets, each 6000 kW.

⋈ Sluice valve.
Non-return valve.
Pipe-rupture valve.
Safety valve.
Throttle valve.
Float valve.

1. Fuel inlet pipe.
2. Electric heating.
3. Fresh air.
4. Exhaust-gas duct.
5. Exhaust to atmosphere.
6. Overflow.
7. Raw water.
8. Cooling-water inlet.
9. Cooling-water outlet.

well-known reasons. On the basis of thorough investigations, the Oslo Electricity Works decided on the following live-steam conditions:—

Steam pressure at boiler outlet: 28 kg/cm^2 abs.
Steam temperature at boiler outlet and at full load: 425^0 C.

Further, to meet local conditions and the object to be fulfilled, as well as on account of the season when the plant would be most used, the following conditions were laid down:—

Kind of cooling water	sea water
Average temperature	5^0 C.

Cooling-water supply is assured by connection to two 300-m long pipe lines of 1000 mm bore, one for the inlet and one for the outlet. These pipes connect the power station to the harbour. The floor of the pump house is at level + 1·34 above the average sea level, so that the conditions for water supply are excellent.

The electric data for the 50-cycle system is:—

Voltage of main bus-bars . .	30 kV.
Voltage of auxiliary bus-bars . .	5 kV.

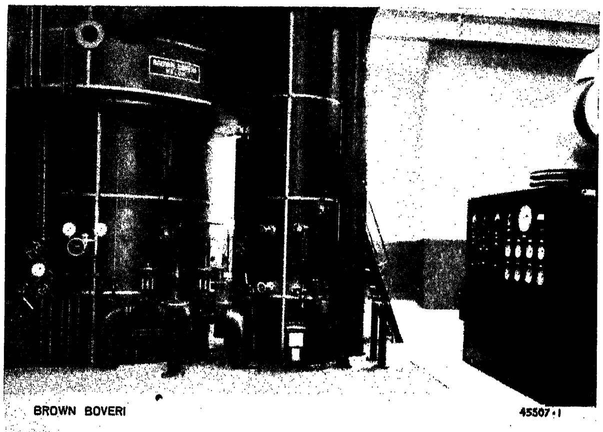


Fig. 7a. — Velox steam generator control post with measuring and control panel.

COMPOSITION OF THE PLANT.

The main parts of which the plant is made up are:—

2 Velox steam generators with auxiliaries.

1 turbo-set comprising the steam turbine, the condensing plant with auxiliaries, the turbo-generator, with accessories and the main transformer.

1 equipment for feed-water treatment and delivery and fuel treatment and delivery; pipes for cooling water and for steam; combustion-air ducts, hot-gas channels and exhaust-gas channels.

2 travelling crane for machinery hall and boiler room.

1 switchgear plant with connections to the 30-kV and 5-kV bus-bars.

1 power-distribution plant for all auxiliaries.

Fig. 6 shows how the boiler plant and the machinery plant as well as all auxiliary devices on the mechanical side are connected together; while the diagrams in Figs. 27 and 29 show all the electrical connections.

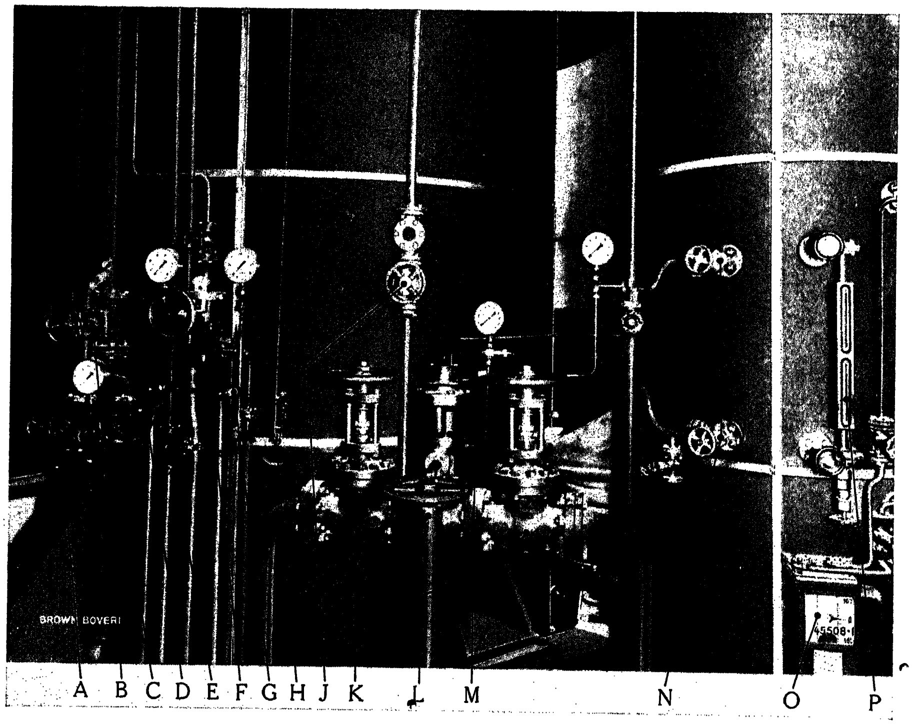


Fig. 7b. — Apparatus for operating a Velox steam generator.

A. Emptying the fuel pipe to the nozzle.
B. Fuel sluice valve before fuel nozzle.
C. Sluice valve on fuel circulation pipe.
D. and G. Relief valve for governing oil, with hand regulation.
E. Three-way cock for governing oil.
F. Steam-pressure regulator.
H. Ignition rod inlet device.
J. Hot-steam sluice valve for fuel preheating.
K. Closing-off sluice valves before and after automatic feed valve.
L. Hand-feed valve.
M. Automatic feed valve.
N. Connection of automatic feed-water governing.
O. Recording nivometer.
P. Water resistance.

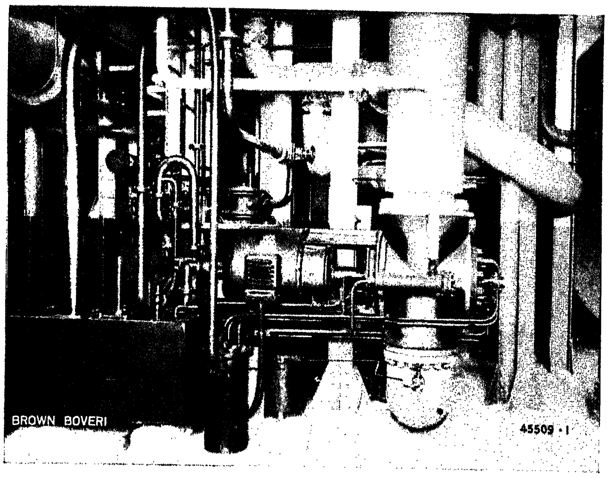


Fig. 8. — Circulation and governing-oil pump set of Velox steam generator with connection piping.

THE VELOX STEAM GENERATOR.

Each of the two steam generators is built for the following conditions:—

Maximum one-hour steam output in continuous service	75 tons.
Feed-water temperature	60° C.
Fuel	fuel oil.

Total power required for charging set, circulation pump, fuel pump at the max. steam output and 20° C surrounding air temperature (without boiler make-up water pump) 183 kW.

Both steam generators, together, cover the maximum steam requirements of the turbo-set with a 10 % margin. As regards the design, it corresponds to the modern standard design which is the result of ten-years development work and more than three years of experience in practical Velox operation. The said design is described in the January number 1935 of The Brown Boveri Review and in other publications, in detail. The big cylindrical containers, such as the combustion chamber, steam separator and economiser are vertically mounted and placed beside each other, while the charging set is of horizontal design. This layout is advantageous from the point of view of the area taken up, further, all inner parts are accessible for the crane. The superheater pipe coils are counter-sunk in the evaporator elements and can be taken out separately if required. The circulation pump is combined with the governing oil pump to form a set (Fig. 8) and located in the basement.

The organs used for starting up and which have to be supervised in operation can be served from a control post from which the supervisory instruments mounted on a common board near the Velox can be read (Fig. 7a). From this point, as well, the auxiliary Velox motors are started, with the exception of the motors of the feed-water set and the Ward-Leonard set.

All auxiliaries are driven by electric motors; a Ward-Leonard set provides for the speed variation of the charging set, over the requisite wide range. Detailed technical data on these auxiliaries will be found in Table I under "List of all auxiliaries installed in the plant" on page 242.

The regulation of the Velox units is entirely automatic. Fig. 9 shows the principle of feed-water, fuel and combustion air regulation; thus, it is not necessary to give a detailed description thereof. The photographic view of the control post (Fig. 7b) shows very clearly how simple and handy these organs are in a Velox steam generator. It will be seen, at once, how very accessible all parts are. The regulating possibilities are excellent thanks to these devices. The Velox can adapt itself to all load variations occurring in service, without the safety valve blowing off when the load is suddenly cut off, or water being carried into the steam pipes when the load is, suddenly, increased. The excellence of the mechanical separation

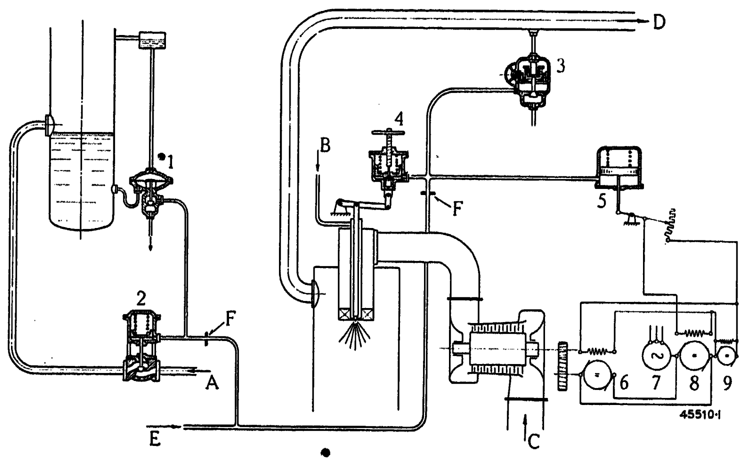


Fig. 9. — Fundamental diagram of the automatic governing of the Velox steam generator for feed-water, fuel and combustion air.

1. Feed-water level governor.
2. Automatic feed-water valve.
3. Steam-pressure regulator.
4. Automatic operation of fuel nozzle.
5. Automatic operation of combustion-air delivery.
6. D. C. motor.
7. Three-phase motor.
8. D. C. motor.
9. Exciter.

A. Feed-water inlet. B. Fuel oil inlet. C. Air suction inlet. D. Live-steam pipe. E. Governing-oil inlet. F. Diaphragm.

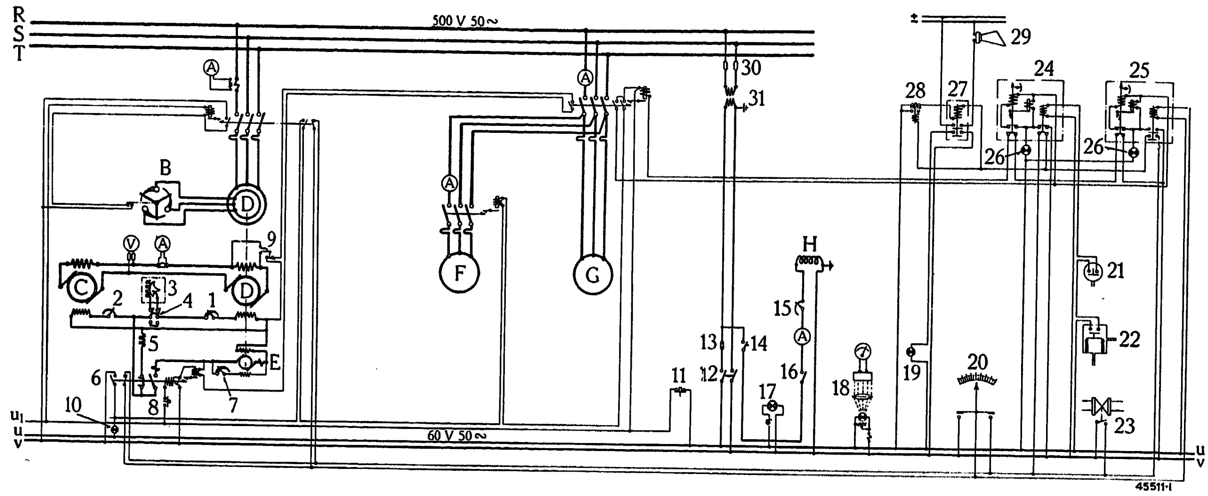


Fig. 10. — Diagram of the electrical equipment of the Velox steam generator.

B. Starter.
C. Motor of charging set.
D. Ward-Leonard converter set.
E. Exciter.
F. Motor of fuel pump set.
G. Motor of circulation pump set.
H. Ignition rod.

1. Field regulator.
2 and 7. Setting resistance.
3. Autom. field regulator (combined with 5 = autom. operation of combustion-air delivery in Fig. 9).
4. Change-over switch.
6. Field switch.
8 and 11. Push buttons.
9. Relay with thermal release.
14 and 16. Stotz automat.
18. Testing gear for combustion gases.
20. Record. nivometer.
21. Relay for lubricating-oil pressure.
22. Differential pressure regulator of circulation pump.
23. Contact on live-steam sluice valve.
24. Time-setting apparatus for difference of pressure of circulation pump.
25. Time-setting apparatus for water level.
27. Contact relay.
28. Push-button with holding coil.
29. Alarm horn.
31. Auxil. transformer 500/60 V.

of water and steam in the water-steam separator is best shown by the results attained on a 45 t/h Velox. These tests were carried out by the Swiss Boiler Owner Association, the passage in the report, dated 9th January 1937, on this subject reading as follows:—

"During these acceptance tests, the water content of the steam before it entered the superheater was measured by a throttle-type calorimeter. It was, thus, shown that, over the whole range of load, there is a, practically, perfect separation of water and steam in the separator, a factor of importance for the operating safety of the steam generator and especially for the steam turbine connected thereto".

The importance of this question is generally recognized and, based on tests carried out earlier on water-tube boilers, a water content of from 0·5 to 2 % had to be reckoned with, according to Erberle[1], a figure which was, however, frequently exceeded.

Although there is little likelihood of the simple organs, which make up the automatic regulation, breaking down, each Velox is equipped with a series of safety devices, which warn the operators in case of trouble or which stop the Velox, if necessary.

[1] See Ch. R. Eberle's publication in "Archiv für Wärmewirtschaft und Dampfkesselwesen", Oct. 1929; also "Forschungsheft 341 des VDI-Verlages".

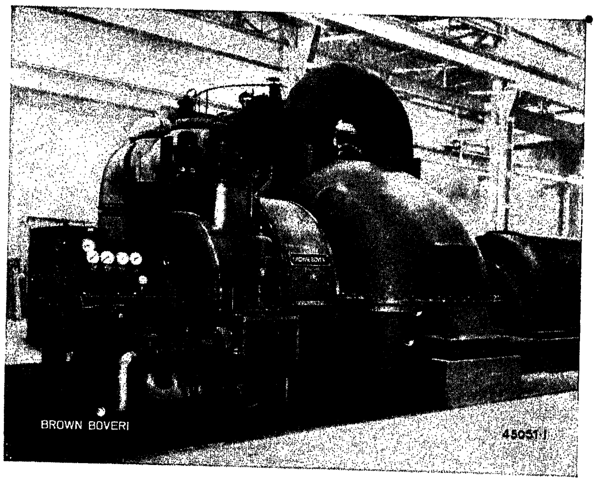


Fig. 11. — Turbo-set seen from live-steam end.

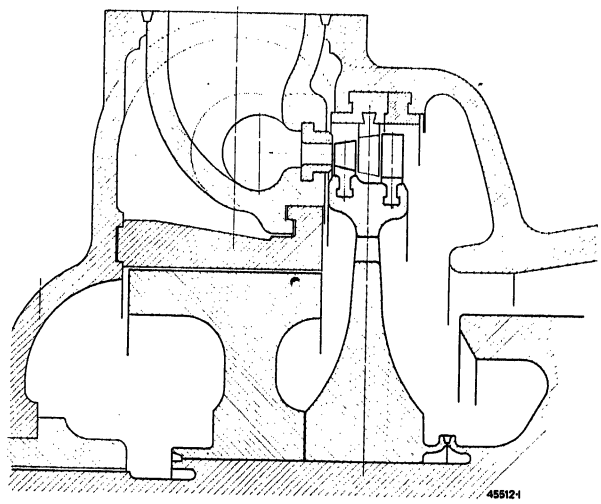


Fig. 13. — Method of securing impulse wheel and balancing piston by safety welding.

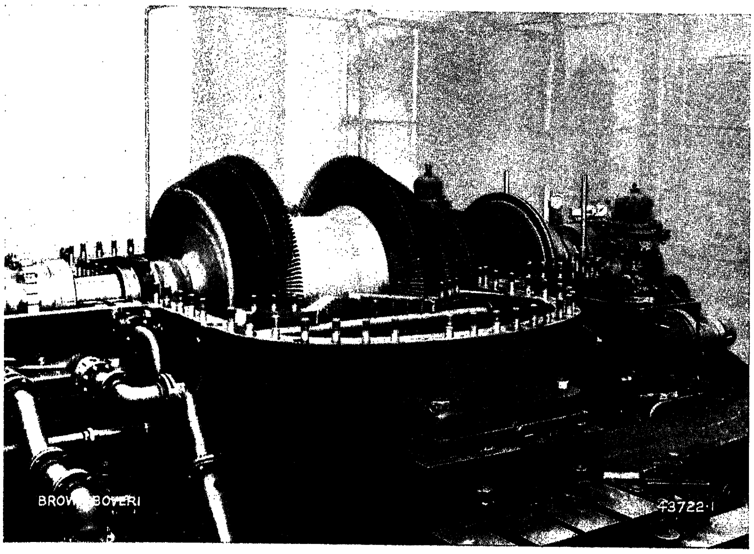


Fig. 12. — Steam turbine with upper part of cylinder raised; on the test bed.

Simultaneously with the warning, the site of the trouble is indicated. This apparatus is all electrically controlled as is shown in the diagram given in Fig. 10.

THE TURBO-SET.

The technical conditions which the turbo-set has to meet are already determined, in part, by the principle service conditions already specified. As regards the steam characteristics, certain losses in the piping have to be taken into account and these were liberally reckoned with when the fundamental calculations were made. The characteristics forming the base of the said calculations are:—

Live steam pressure at turbine inlet: 27 kg/cm^2 abs.
Live steam temperature at turbine inlet: 420^0 C.
Vacuum under max. continuous load conditions: 0·034 kg/cm^2 abs.
Maximum continuous load measured at generator terminals: 31,500 kW.
Speed of set 3000 r. p. m.

A total of 1500 kW was reckoned with to cover all the requirements of station auxiliaries, and this was a very liberal computation, as will be seen further on; the useful load is, therefore, at least 30,000 kW.

(a) *The steam turbine.*—There was no difficulty encountered in lodging the 32,000-kW terminal capacity demanded in a single-cylinder steam turbine of the 3000 r. p. m. type, with a single-ended low-pressure part. This is the simplest and cheapest solution and was put forward by other parties for this same station. We would only recommend it for plants working to a low vacuum, such as occurs in stations using cooling towers. When, however, the cooling water conditions are favorable, as is precisely the case here, we are of the opinion that this design, even in the case of a peak-load plant, is not the one to be adopted, because the exhaust losses of the single-ended turbine are exceptionally high. The difference in efficiency as compared to a double-ended turbine is considerable and, on the other hand, the difference in purchasing costs is, relatively, small, so that even with a low loading factor, the result of a calculation of economy is in favour of the more expensive turbine design.

By adopting special measures, it was found possible to design a type of single-cylinder turbine at 3000 r. p. m. for this big output, having the advantage of low exhaust losses and which works not only economically at the maximum load, but gives an excellent,

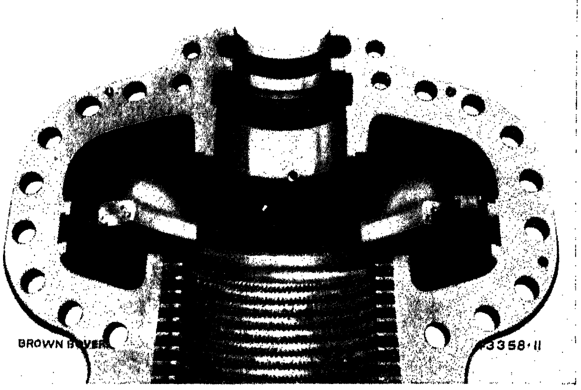


Fig. 14. — View into upper part of turbine housing with built-in nozzle chest.

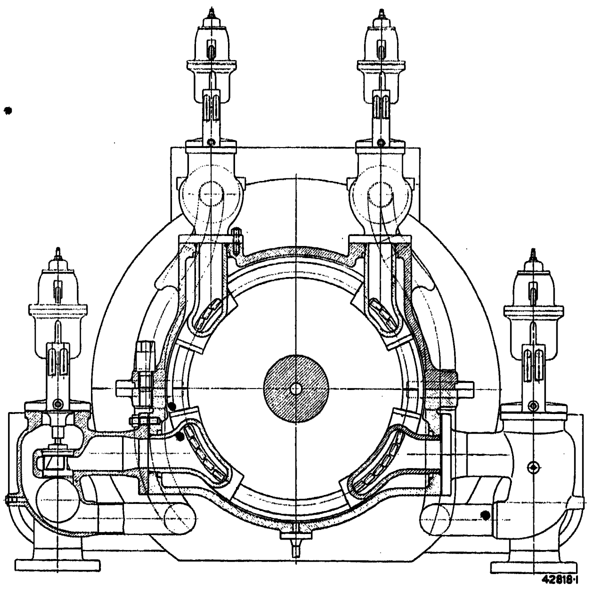


Fig. 15. — Section of high-pressure part of turbine.

flat efficiency curve over a wide load range. We will limit ourselves, here, to the observation that the solution of the problem is, solely, due to the use of two low-pressure steam parts working in counter sense to one another. Very exhaustive investigations and tests were required in order to reach a satisfactory solution of the problem of the best way to guide the steam in the exhaust branches. As is known, machines of similar interior design but of smaller output have been put on the market. The results obtained therewith were not satisfactory, as the two opposed flows of exhaust steam reacted deleteriously on one another.

The design of the most interesting part of this turbines, which is the rotor, formed of different parts welded together, has already been described in the January Number 1936 of The Brown Boveri Review. Fig. 11 shows the turbine completely erected in the foreground and Fig. 12 gives a view of the machine open.

The axial thrust is also reduced by this double-ended arrangement in the low-pressure part, so that a small balance piston which is the seat of low losses, only, is sufficient.

The blade lengths are, throughout, the most advantageous possible, further, it was found possible to lodge a big ΣU^2 in the unit, which is only slightly below that of the corresponding multi-cylinder machine; an efficiency results which is high for a single-cylinder turbine.

The use of four live-steam nozzles gives good utilization of the steam at partial loads, as well.

The water drainage from the last low-pressure stages is very carefully designed, so that about 30 % of the water is eliminated.

As to the composition of the blading itself, material which is most suitable to the respective zones is used:— nickel steel, chromium-plated steel and rustless steel. The last low-pressure stages are composed, solely, of rustless steel and are hardened along the inlet edge by a special process against erosion. This latter is a Brown Boveri patent which has given excellent results; it is indispensable in machines working to a high vacuum.

From the point of view of design, it is especially interesting that the balance piston and the impulse wheel are shrunk on but are not secured by keys, having, instead, a safety welding; this eliminates once for all, the well-known trouble of discs working loose (Fig. 13). The way the nozzle chests are fitted into the turbine casing is, also, of interest; they are suspended in the casing and welded to the latter on the outside; thus, the high temperatures are prevented from reaching the casing and the latter can be made to a very simple design (Fig. 14). The same object is pursued and a reduction of thermal stresses attained in the high-pressure part, by the arrangement of the governing valve casings outside the impulse wheel casing, as is shown in Fig. 15.

The live steam is led to the turbine through two main stop valves. These valves each form an entity with one of the four nozzle valves, one on each side of the turbine. Strongly bent and correspondingly flexible high-pressure pipes form the connection to the two remaining built-on nozzle valves. The turbine is equipped with the well-known Brown Boveri oil-pressure governing system in its latest design. As Fig. 16 shows, the main stop valves are, also, governed by oil under pressure; the earlier worm-wheel drive of the governing shaft has, also, been replaced by the more reliable spur-wheel drive with inclined teeth.

(b) *The condensing plant.*— It is laid out for the following conditions:—

Kind of cooling water	sea water.
Average cooling-water temperature .	5 ° C.
Available quantity of cooling water, incl. quantity requisite for plant auxiliaries such as air extraction, closed-cooling system for generator, etc. .	5000 m^3/h.
Surface of condensers . . .	2000 m^2.

In the present case, the standard Brown Boveri OV type of condenser introduced by Brown Boveri with success decades ago has not

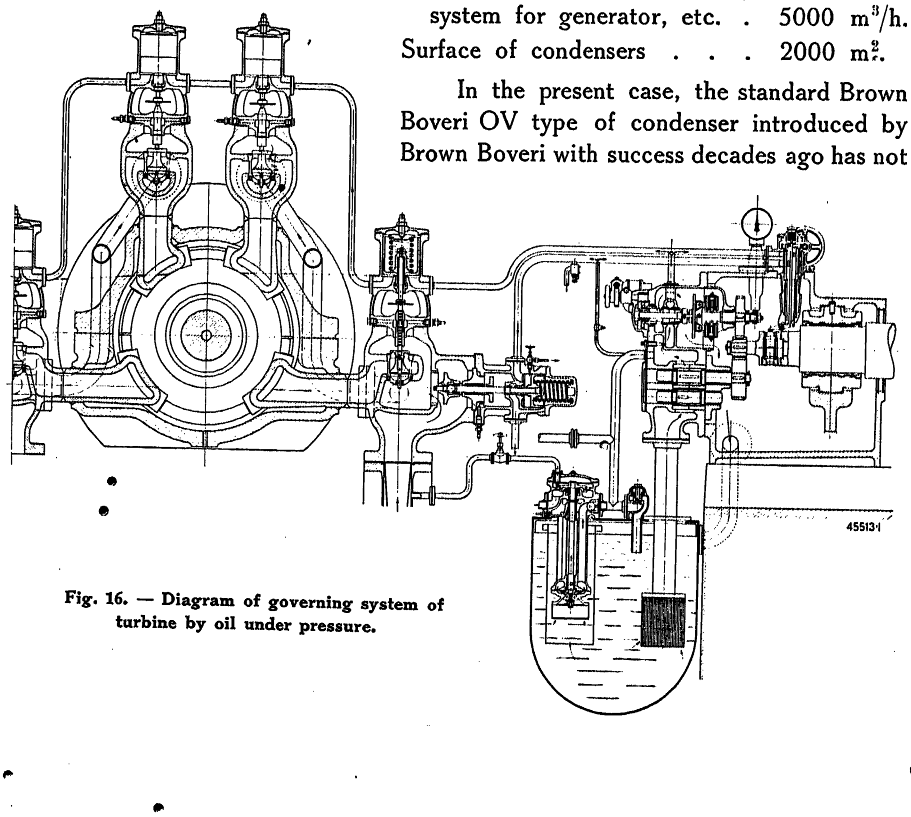


Fig. 16. — Diagram of governing system of turbine by oil under pressure.

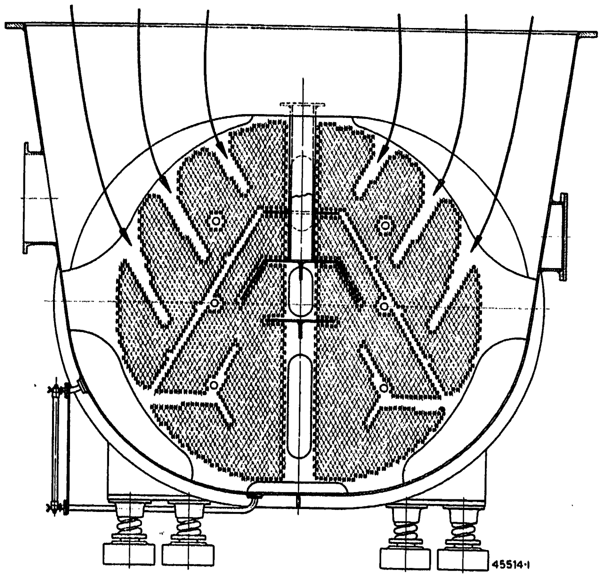


Fig. 17. — Section through surface condenser.

been used. The two-ended low-pressure parts of the turbine calls for a big exhaust-steam branch. For this reason and because of the longitudinal layout of the body of the condenser it was found advisable to reverse the OV principle, in so far that the steam is not led in through a wide V-shaped central passage between the tube-stack halves but that, here, the stack of cooling tubes is subjected to the flow of steam from the outside and over its whole periphery. This arrangement is as advantageous, from the point of view of the utilization of material, as the well-known OV principle, the resistance to the flow of steam is just as low and is further reduced by deep channels. Deaeration is located in the central tube-stack zone. As Fig. 17 shows, a considerable number of cooling tubes are reserved, there, for air cooling.

Since some years back, Brown Boveri have been using condenser tubes expanded into the tube plates, with most satisfactory results [1]. This process gives better sealing properties against the penetration of cooling water into the condensate and it also allows of increasing the resistance of the expensive condenser tubes against the attacks by corrosion; the expansion into the tube plates at both ends allows of utilizing softer material for the tubes, which is considerably more resistant to corrosion than the harder material, used before, when the condenser tubes were secured by glands in the tube plates. We would recall, here, the thorough investigations carried out some years ago by Brown Boveri to solve the problem of the resistance of condenser tubes, the valuable results of which were published in the October 1934 number of The Brown Boveri Review, page 180:— "The corrosion of copper-nickel alloys" by Dr. H. Stäger and J. Biert.

In other respects, this condenser corresponds to the Brown Boveri standard sea-water design. The tube plates are composed of Muntz metal and the alloy used for the tubes themselves is 70 % copper, 29 % zinc and 1 % tin; the two water chambers are of cast iron. The condenser body is supported on springs and rigidly bolted to the exhaust-branch flange of the turbine.

The auxiliary machines of the condensing plant are composed of two cooling-water pump sets and two combined condensate and ejector-pump sets. The cooling-water pumps are so dimensioned that, together, they cover the cooling-water requirements of the condensing plant and all auxiliary devices such as oil coolers, closed-circuit generator coolers, etc., without the main transformer, at maximum continuous load. Of the combined condensate and ejector-pump sets, one suffices, even under overload conditions, the other being a stand-by. All these pump sets are electrically driven; Table I contains data on the three-phase motors used to drive the pumps.

(c) *The turbo-generator.*—It is built to the following conditions:—

Terminal output at p. f. = 0·9	35,000 kVA.
Terminal voltage	6,600 V.
Frequency	50 cycles.

[1] See The Brown Boveri Review of January/February 1937 for details on this design.

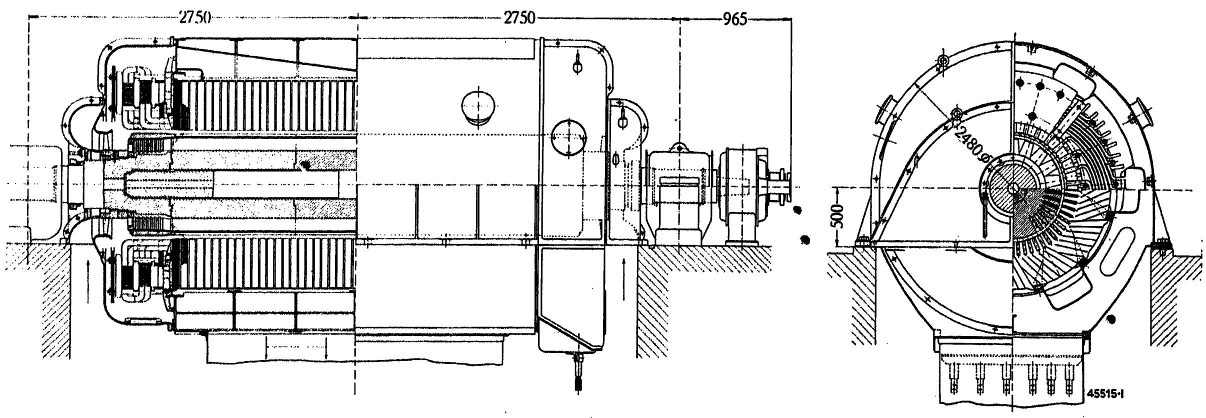


Fig. 18. — Cross and longitudinal section of the three-phase generator 35,000 kVA, 3000 r. p. m., 6600 V.

The active iron laminations are secured in the steel housing by anti-magnetic dovetail keys (Fig. 18). A conductive connection between the key ends by means of copper bars acts as a protection against eddy currents for keys and housing and allows of keeping down the losses due to this cause. This Brown Boveri design has been in use since some years and is protected by patent DRP 314 202, this is stressed here, as the said design has, lately, been put forward by other parties as a valuable innovation.

The stator slots are of the enclosed type, which is a very advantageous form as regards losses and cooling. They can be used, here, thanks to a new winding method which has the advantage of allowing the exchange of separate coils.

There are two bars per slot, which bars are of the well-known transposed type, to reduce extra losses. Each bar and a complete coil-end connection piece forms an entity, so that the subdivision of the active copper section is also carried out in the frontal connection piece and is not limited to the copper in the stator slot proper. In order to impart the requisite mechanical rigidity to the subdivided copper it is baked with artificial resin so as to make it a massive whole.

The insulation is a mica preparation with a special varnish of high dielectric, thermal and mechanical qualities as binder.

Stout bolts support the stator coil ends; these are made of anti-magnetic steel. In all supports, metal parts are avoided, as far as is possible and hard paper parts used instead, in order to lower the additional losses. To the same end, the rim of pressure fingers on the end teeth, which compress the laminations, are made of bronze, further the shields, of an alloy containing much aluminium, placed on the stator ends do much to lower the said losses.

The rotor body is made up of different parts, which is a Brown Boveri patented design (DRP 558 384). The parts which make up the cylindrical rotor are mounted on a central bolt running the whole length of the rotor proper. This bolt has a thread at each end on which the last of the said rotor elements with the respective shaft ends are screwed (Fig. 18). The axial pressure resulting from the screwing-up of these end pieces is so great, despite moderate stressing, that the rotor behaves statically and dynamically as though it were a solid body. The subdivision into smaller parts allows of better investigation of the material used and facilitates the manufacture, a great advantage in view of the recent increasing difficulty encountered in getting acceptable delivery times for big forgings. Only sufficient material is milled out of the rotor as is necessary to form the slots for the rotor winding. There are no axial slots for ventilation, thus any danger of dirt deposits is eliminated and the teeth remain as thick as they can be, which, apart from the mechanical advantages thereof, also guarantees a desirable field curve. The coil ends are secured by end caps of anti-magnetic steel of great strength.

A new preparation of asbestos and artificial resin is used to insulate the rotor winding. It combines great mechanical strength and excellent electrical properties. It stands up well to heat and, therefore, offers the necessary security against the results of high and alternating heating up. The heat expansion is of the same order of magnitude as that of the metals and the heat conductivity is nearly double that of mica preparations.

Brown Boveri succeeded in developing a process by which the coils in the slots are baked together at full speed, so that the separate conductors, under the enormous centrifugal force they are subjected to, adhere together so tightly that they acquire the characteristics of a solid body. With this treatment, further, all air pockets are entirely eliminated and, thus, favourable conditions are created for carrying off heat and only slight differences of temperature occur between copper and iron.

The demand for simplicity of the plant called for built-in fans, which are mounted at each end of the rotor and which are designed as axial ventilators, according to the latest practice.

The excitation current is delivered by an overhung exciter and carried to the slip rings at the ends of the rotor.

The generator shaft is connected to the turbine shaft by means of a claw coupling. This type of coupling giving freedom to move to each rotor respectively is recommendable on account of the big load and because the rated speed of the rotors is above their critical speeds.

The generator has closed-circuit cooling. Cooling being by ribbed coolers and by sea water delivered by the cooling-water pumps of the condensing plant. Further, there are the usual supervising and alarm devices which come into action if cooling gets deficient. There is also a fire extinguishing CO_2 gas equipment.

To conclude, it should be remarked that the generator-terminal voltage does not coincide with the voltage of the medium-voltage distribution system, which is 5000 V. As local conditions are such that power is not delivered from the new plant into this system, it was considered advisable to choose a generator voltage, independently of the said system voltage, and one which would result in advantageous winding and slot conditions as regards slot harmonics.

(MS 555) *(To be continued.)* *A. Fischer.*

DETERMINATION OF THE BEHAVIOUR OF THE RECOVERY VOLTAGE AFTER RUPTURING SHORT CIRCUITS, BY MEANS OF A HIGH-FREQUENCY RESONANCE METHOD.

Decimal index 621.316.5.064.

I. INTRODUCTION.

BROWN BOVERI has devoted great attention, over a long period, to the problem of the behaviour of the recovery voltage after the rupturing of short circuits.[1] Especially, in the course of the last two years, elaborate tests were carried out, using a cathode-ray oscillograph. Simultaneously, with these efforts, methods of calculation were elaborated and an *experimental* method worked out which allows of determining the behaviour of the recovery voltage *without carrying out short-circuit* tests at all. The present article describes this last method and another article will follow it, shortly, describing the progress made in calculating methods and the tests with cathode-ray oscillographs.

The behaviour of the recovery voltage does not depend alone on the inductivities, capacities and resistances which make up the system, but depends, as well, on the characteristics of the circuit breaker. An "ideal" breaker would not influence the curve of the rupturing current at all, down to its passage through zero and would absolutely prevent the subsequent increase of the current in the opposite sense. The traversing resistance of this "ideal" breaker is, thus, zero down to the passage of the current through zero and then it suddenly becomes infinitely great. Breakers built in practice deviate in two respects from this ideal one. On the one hand, the arc set up at the point of rupture before the current passes through zero constitutes a resistance which cannot be disregarded, in many cases. It causes the current to fall quicker towards zero than in the case of the ideal breaker and an arc voltage is created between the terminals of the breaker. This results in greater oscillations in the recovery voltage, as is shown in Fig. 1. On the other hand, the ionized gases cause a certain conductivity between the open contacts, even after the passage of the current curve through zero and thus damp down the harmonics of the recovery voltage[2].

It is clear that any method which determines the behaviour of the recovery voltage, without it being necessary to carry out short circuit tests, cannot take into account the influence exercised by the breaker. Each of these methods determines the behaviour of the recovery voltage when an "ideal" breaker is used, the definition of which has already been given, or, in other words, it gives the behaviour of the recovery voltage according to the con-

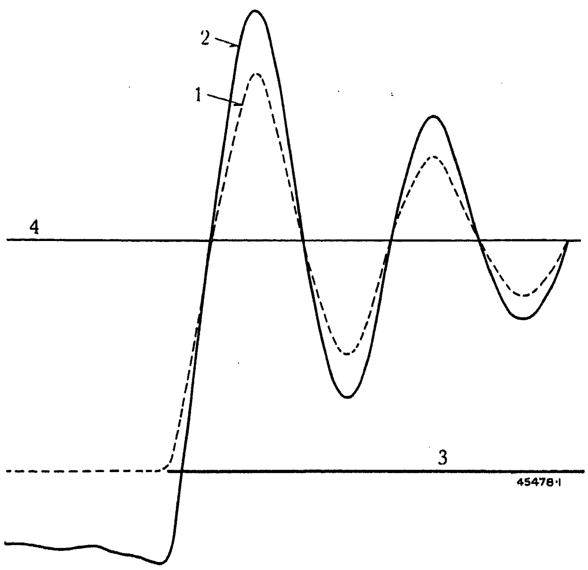


Fig. 1. — Oscillation phenomena of the recovery voltage.
1. With an "ideal" breaker.
2. Under influence of the arc voltage.
3. Zero line.
4. Service-frequency recovery voltage (middle line of oscillations).

[1] J. Kopeliowitch "Neue Forschungsergebnisse über Vorgänge beim Schalten unter Oel", Bull. SEV 1928, page 541.

J. Kopeliowitch "Influence de la forme de la tension de rupture sur le travail des disjoncteurs", Bull. SEV 1931, page 312.

Also compare to the following by the same author:- Bull. SEV 1932, page 570; RGE 1930, vol. XXVII, page 293; c. r. de la Conférence Internationale des Grands Réseaux, 1929, vol. XXVII, page 398.

F. Gubler "Berechnung der Eigenfrequenz der wiederkehrenden Spannung und ihre Bedeutung für die Abschaltleistung", VDE-Fachberichte, 1931.

P. Fourmarier "Sur le calcul de la tension de rétablissement des disjoncteurs", c. r. 2me Congrès National des Sciences, Bruxelles 19th to 23rd June 1935.

[2] In technical literature (see A. M. Cassie, World Power, July 1935, page 13, for example) a further deviation is mentioned between the real and the "ideal" breaker, the *sudden* rupture of the current flowing through the breaker before the standard passage through zero. Of course, the current in the inductivities is not suddenly ruptured but flows into the capacities, charging the latter. The speed of rise of the recovery voltage cannot be infinitely big here. Such sudden ruptures of current which are related to instabilities of the arc only occur for *small* rupturing currents and are, thus, not of interest for the subject treated in this article. This same applies to natural oscillations produced by the arc and being superimposed on the current of standard frequency, thus causing the breaker current to pass through zero and be ruptured at a moment when the currents flowing in the inductivities are not at zero value.

dition on the system. With cathode oscillographic reproduction of short-circuit ruptures, on the contrary, the influence of the breaker itself on the behaviour of the recovery voltage cannot be eliminated. The two methods of measurement thus form a valuable mutual complement one of the other. On the one hand, it is interesting to know the real behaviour of the recovery voltage for a given system and a determined breaker, taking all influences into account, while, on the other hand, it is also important to know to what extent the behaviour of the recovery voltage dictated by the system is influenced, favourably or unfavourably, by the breaker. The measuring methods which do not call for the carrying out of rupturing tests have, further, the advantage that they do not stress the system practically at all and are, thus, much easier to apply than when rupturing tests must be arranged for. A high-frequency method offers further, the fundamental possibility of carrying out the measurements while ordinary service on the system is being carried on.

II. MATHEMATICAL EXPRESSION OF THE RECOVERY VOLTAGE.

According to the Heaviside method, the phenomena which accompany the rupture of an alternating current by means of an "ideal breaker" can be calculated by assuming that at the moment the current passes through zero a counter current of equal strength is suddenly switched on, which, from that moment, equalizes the short-circuit current flowing through the breaker, before. In this way, the symbolic equation [1] given below is found for the recovery voltage:

$$e = I \frac{1}{Y(p)} \cdot \frac{\omega\, p}{p^2 + \omega^2}\, \mathbb{1} \tag{1}$$

e = Recovery voltage.

I = Peak value of ruptured current.

ω = Its pulsation.

$p = \frac{d}{dt}$ = Heaviside operator.

$Y(p)$ = Admittance of system on supply side of the breaker seen from the breaker-terminals, where $j\omega$ which occurs in the complex expression of the admittance is replaced, everywhere, by p.

$\mathbb{1}$ = Heaviside unit function, that is a function which vanishes for $t < 0$ and which has the value 1 for $t > 0$.

From the symbolic equation (1) the real solution is obtained, by means of the Heaviside expansion theorem:—

$$e(t) = I\,\omega \sum_k \frac{\varepsilon^{p_k t}}{Y'(p_k)\cdot[p_k^2 + \omega^2]} + I\,\frac{\cos(\omega t + \delta)}{|Y(j\omega)|} \tag{2}$$

here:—

ε = Basis of the natural logarithm.

Y' = First differential coefficient of Y.

δ = Phase angle of the admittance Y at standard system frequency.

The values p_k, which have to be introduced under the summation sign are the roots of the equation:—

$$Y(p) = 0. \tag{3}$$

The member

$$\frac{I\cos(\omega t + \delta)}{|Y(j\omega)|}$$

represents the part of the recovery voltage belonging to the service frequency, there are high-frequency waves superimposed thereon. For the high-frequency wave of the order of k the following equation is valid:—

$$e_k = I\,\omega \frac{\varepsilon^{p_k t}}{Y'(p_k)\,(p_k^2 + \omega^2)} \tag{4}$$

As, in most cases, p_k is big[2] with regard to ω, the following equation can be set down without committing a serious error:—

$$e_k = I\,\omega \frac{\varepsilon^{p_k t}}{Y'(p_k)\cdot p_k^2} \tag{5}$$

The circuit, which is being interrupted, is made up of inductivities, capacities and resistances which are, either, concentrated in one spot or distributed over the system. For this reason, the functions Y and Y' may have any composition of powers of p or hyperbolic functions of p. The roots of the equation (3) are either real or complex conjugate pairs.

In the case of real values of p_k, equation (5) represents an aperiodic damped oscillation, in the case of conjugated complex values of p_k, a periodic, damped, oscillation. As the recovery voltage without the damping influence of the breaker, which is excluded here as the one being used is of "ideal" type, is usually very slightly damped, only the latter case, that of the periodic oscillation is examined here. The real component of p_k is always negative; because, in the case of positive real components, the equation (5) would represent an oscillation which builds up, and this is physically impossible in the case under consideration.

Therefore:—

$$p_k = -\alpha_k \pm j\,\omega_k. \tag{6}$$

If these two values are inserted in equation (5) and if the expressions thus reached are added, the

[1] The symbolic method of calculation introduced by Heaviside is described, for example, in the volumes:—

John R. Carson "Electric circuit theory and the operational calculus" ("Elektrische Ausgleichsvorgänge und Operatorenrechnung". Increased German works by F. Ollendorff and K. Pohlhausen. Printed by Julius Springer, 1929.)

E. J. Berg "Heaviside's Operational Calculus as applied to Engineering and Physics". Publishers: Mac Graw-Hill, New York and London, 1929.

[2] The absolute value of p_k agrees in the essential as will be shown later (equ. 9b) with the pulsation of the k^{th} natural oscillation of the recovery voltage.

rules of the Heaviside expansion theorem lead to:—

$$e_k = 2\,I\,\omega\,\frac{\varepsilon^{-\alpha_k t}\cdot\cos(\omega_k t + \delta_k)}{|Y'(p_k)\cdot p_k^2|} \tag{7}$$

in which δ_k has to be determined from the equation:—

$$\frac{1}{Y'(p_k)\cdot p_k^2} = \frac{1}{|Y'(p_k)\cdot p_k^2|}\,\varepsilon^{j\,\delta_k} \tag{8}$$

Now, it can be shown that δ_k is very small; further, numerous measurements have shown that

$$\alpha_k << \omega_k \tag{9 a}$$

therefore:—

$$|p_k^2| = \alpha_k^2 + \omega_k^2 \approx \omega_k^2 \tag{9 b}$$

and

$$|Y'(p_k)| = |Y'(-\alpha_k + j\,\omega_k)| \approx |Y'(j\,\omega_k)|\cdot \tag{9c}$$

With these assumptions it can be easily shown that:—

$$\delta_k \approx o \tag{9 d}$$

This is easy to grasp, physically. If the system has no resistances at all and only inductivities and capacities, δ_k vanishes altogether and when the active component in the admittance Y of the system is small as compared to the reactive one (which is, finally, the meaning of equation 9a); then δ_k is also small. For conditions encountered on systems it is sufficiently correct to set down:—

$$e_k = 2\;I\;\omega\,\frac{\varepsilon^{-\alpha_k t}\cdot\cos(\omega_k t)}{|Y'(j\,\omega_k)|\cdot\omega_k^2} \tag{10}$$

this means that the recovery voltage is composed of damped-down cos functions (practically without phase displacement). The initial value of the k[th] harmonic (for $t = 0$) will be

$$E_k = \frac{2\;I\;\omega}{|Y'(j\,\omega_k)|\cdot\omega_k^2} \tag{11}$$

III. DETERMINATION OF THE FREQUENCIES AND AMPLITUDES OF THE DIFFERENT NATURAL OSCILLATIONS.

If the admittance of the system is measured from the breaker terminals and if its absolute value is set down in function of the frequency, the curve obtained has a minimum for each natural frequency ω_k of the system. This should be well enough known so that it need not be deduced, here, from equations (3), (6) and (9a).

However, the amplitudes of the different natural oscillations can be ascertained as well from this admittance curve. If we set down for the complex admittance of the circuit:—

$$Y(j\,\omega) = \varphi(j\,\omega) + j\,\psi(j\,\omega) = \varphi + j\,\psi \tag{12}$$

in which φ and ψ are real values, the absolute value of the admittance is:—

$$|Y(j\,\omega)| = \sqrt{\varphi^2 + \psi^2}\cdot \tag{13}$$

As was just mentioned, this magnitude has a minimum for each natural frequency ω_k. If the system should not contain any resistances (natural oscillations undamped), this magnitude for

$$\omega = \omega_k$$

would be equal to zero. As the influence of the damping was mostly ignored in the preceding mathematical deductions, the influence of the damping must also be eliminated in the measured admittance curve. This can be achieved for the resonance region by subtracting quadratically the value of the admittance at the resonance point from the values of the curve. Thus, the following function is formed:—

$$Y(\Delta\omega) = \sqrt{|Y(j\,\omega)|^2 - |Y(j\,\omega_k)|^2} \tag{14}$$

in which

$$\Delta\omega = \omega - \omega_k$$

and

$$Y(j\,\omega_k) = \varphi_k + j\,\psi_k.$$

Taking equation (13) into account we get:—

$$Y(\Delta\omega) = \sqrt{(\varphi^2 + \psi^2) - (\varphi_k^2 + \psi_k^2)}\cdot \tag{15}$$

For small values of $\Delta\omega$ the following equations are valid:—

$$\left.\begin{aligned}\varphi &= \varphi_k + \varphi'_k\cdot\Delta\omega\\ \psi &= \psi_k + \psi'_k\cdot\Delta\omega\end{aligned}\right\} \tag{16}$$

If these values are substituted in equation (15) the following equation results:

$$Y(\Delta\omega) = \sqrt{2(\varphi_k\,\varphi'_k + \psi_k\,\psi'_k)\cdot\Delta\omega + (\varphi'^2_k + \psi'^2_k)\cdot(\Delta\omega)^2} \tag{17}$$

As the absolute value of the admittance shows a minimum for position ω_k, the first differential coefficient of equation (13), for this point, is equal to zero, i. e. the first expression under the root of equation (17) vanishes and there remains:—

$$\frac{Y(\Delta\omega)}{\Delta\omega} = \sqrt{\varphi'^2_k + \psi'^2_k} = |Y'(j\,\omega_k)|\cdot \tag{18}$$

Now, to determine the amplitude of the k[th] natural oscillation the absolute value of the measured

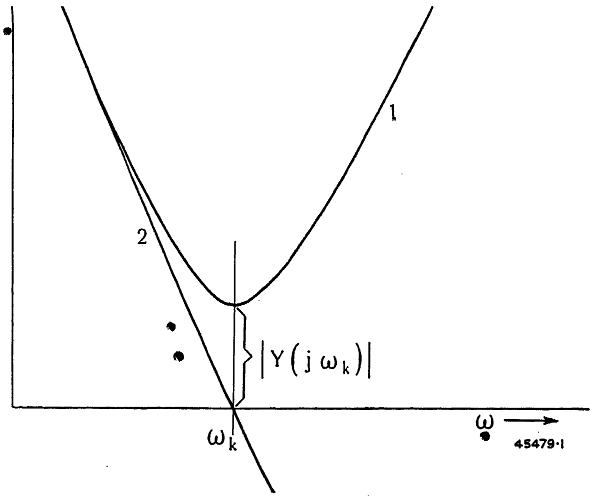


Fig. 2. — Admittance curves.

$1 = |Y(j\omega)|$ $\qquad 2 = \sqrt{|Y(j\omega)|^2 - |Y(j\omega_k)|^2}$.

admittance is put in in function of the frequency (curve 1 in Fig. 2) and curve 2 of Fig. 2 is built up according to equation (14). The tangent to this curve is drawn in at ω_k and the angle of inclination of the tangent is measured. This value is identical with the left side of equation (18) and coincides with the absolute value of the first differential coefficient of Y, according to this equation. Thus, it is possible, by constructive means, to determine $|Y'(j\,\omega_k)|$ according to Fig. 2. There only remains to insert this value in equation (11) in order to obtain the amplitude of the k^{th} natural oscillation.

IV. DETERMINATION OF THE DAMPING COEFFICIENTS OF THE DIFFERENT NATURAL OSCILLATIONS.

According to equation (7) each transient member — apart from the interrupted current I and its pulsation — is only dependent on the complex natural frequency p_k (with its components α_k and $j\,\omega_k$) and the first differential coefficient of the admittance Y at the point p_k. Thus, exactly the same equation (7) is valid for different systems if only a zero value of the admittance is situated at the same value of p_k for all the systems and if the first differential coefficient of the admittance has the same magnitude for all systems at the value p_k. Especially, a simple system having only one natural frequency behaves, under these assumptions, for frequency ω_k in about the same way as any complicated system. Therefore, one can simplify the calculations by reckoning only for the case of this simple system. Fig. 3 illustrates the most general system with only one natural frequency. According to Heaviside, the symbolic admittance for this system is: —

$$Y(p) = \frac{1}{\varrho} + \frac{LCp^2 + RCp + 1}{Lp + R} \qquad (19)$$

and the complex natural frequency will be, in the case of not too powerful damping: —

$$p_k = -\alpha_k + j\,\omega_k \qquad (20)$$

in which: —

$$\alpha_k = \frac{\varrho RC + L}{2\varrho LC}; \quad \omega_k = \frac{1}{\sqrt{LC}} \qquad (21)$$

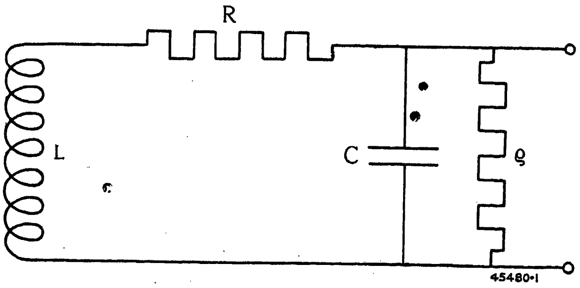


Fig. 3. — General system with a single natural frequency.

If the last two values are inserted into equation (19) and if R is disregarded as compared to ϱ (as R is small for weak damping, while ϱ is big) the following equation may be set down: —

$$Y(p) = C\,\frac{p^2 + 2\alpha_k\,p + \omega_k^2}{p + \dfrac{R}{L}} \qquad (22)$$

The first differential coefficient is: —

$$Y'(p) = C\,\frac{p^2 + 2\dfrac{R}{L}p + 2\dfrac{R}{L}\alpha_k - \omega_k^2}{\left(p + \dfrac{R}{L}\right)^2} \qquad (23)$$

If, now, these two equations are divided one by the other and if $p = j\,\omega_k$ is assumed then: —

$$\frac{Y(j\,\omega_k)}{Y'(j\,\omega_k)} = \frac{j\,\alpha_k\,\omega_k\left[j\,\omega_k + \dfrac{R}{L}\right]}{-\omega_k^2 + j\dfrac{R}{L}\omega_k + \dfrac{R}{L}\alpha_k}. \qquad (24)$$

If $\frac{R}{L}\alpha_k$ is disregarded as compared to ω_k^2 the following result is, finally, attained: —

$$\frac{|Y(j\,\omega_k)|}{|Y'(j\,\omega_k)|} = \alpha_k \qquad (25)$$

$|Y'(j\,\omega_k)|$ has been ascertained in the foregoing chapter. $|Y(j\,\omega_k)|$ can, also, be read off the admittance curve (compare to Fig. 2). Thus the damping coefficient can be ascertained from the admittance curve, according to equation (25), which is the coefficient appearing in equation (10) for the recovery voltage.

V. DETERMINATION OF THE SHORT-CIRCUIT INDUCTIVITY.

If the abbreviation: —

$$L_k = \frac{2}{|Y'(j\,\omega_k)|\,\omega_k^2} \qquad (26)$$

is inserted into equations (10) and (11), the equation for the k^{th} natural harmonic becomes: —

$$e_k = I\,\omega\,L_k\,\varepsilon^{-\alpha_k t}\cos(\omega_k t) \qquad (27)$$

and that for the initial value of this oscillation: —

$$E_k = I\,\omega\,L_k. \qquad (28\,a)$$

L_k has the dimension of an inductivity and can be determined for a given voltage amplitude E_k from the equation: —

$$L_k = \frac{E_k}{I\,\omega} \qquad (28\,b)$$

As the sums of all initial values E_k of natural harmonics are equal and opposed to the peak value E of the stationary voltage, therefore (apart from the sign)

$$\sum_k E_k = I\,\omega \sum_k L_k = E = I\,\omega\,L$$

and

$$\sum_k L_k = L \tag{29}$$

L is the short-circuit inductivity of the system, seen from the breaker-terminal side. The total short-circuit inductivity L can be split up, according to equation (29) into a number of partial inductivities, to each of which a determined natural frequency is inherent.

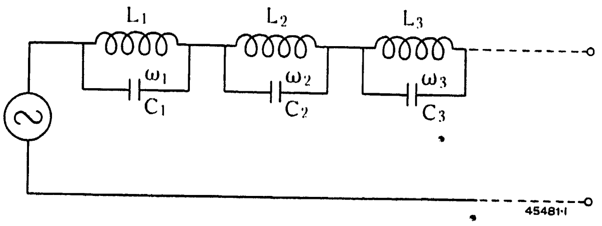


Fig. 4. — Substituted diagram for a harmonic circuit with several natural frequencies.

This subdivision comes to the same thing as a reduction of the system investigated to the arrangement shown in Fig. 4. In this arrangement each separate circuit (L_k C_k) can oscillate according to its natural frequency ω_k and independently of the other separate circuits and, when a short-circuit current is interrupted, each separate circuit oscillates with the peak value of the voltage which was present along its inductivity before the interruption took place. Instead of expressing the peak value of the k[th] natural oscillation in volts, the L_k belonging thereto can be given in Henry. This gives that share of the total short-circuit inductivity the voltage drop of which oscillates with the natural frequency ω_k.

If the different L_k are determined by means of the high-frequency method described, the short-circuit inductivity can be ascertained, according to equation (29), that is to say that value which determines the magnitude of the service-frequency short-circuit current. It is, at least, noteworthy that this magnitude should be attainable by purely high-frequency methods. Of course, as regards precision of these measurements, similar reservations must be made as for the measurements of impedance with low frequency at low current. In any case, equation (29) offers a welcome checking method on the amplitudes of the various natural oscillations when the short-circuit inductivity has been ascertained from a measurement with low frequency.

VI. EXPERIMENTAL CHECK-UP ON THE METHOD DEVELOPED.

In the measurement of the admittance in function of the frequency, it is most suitable to use a beat-frequency generator which is connected to the terminals of the open breaker by means of a transmitter and which impresses the changeable frequency on the system at that point. The determination of the admittance by means of current and voltage measurement offers no special difficulty, here.

To check the high-frequency resonance method developed, various system layouts were subjected to measurement the said systems being such that the behaviour of the recovery voltage could either be easily calculated or ascertained from cathode oscillographic records. A couple of tests of this kind are given in the Table on page 222. Fig. 5 shows the complete analysis for the first test.

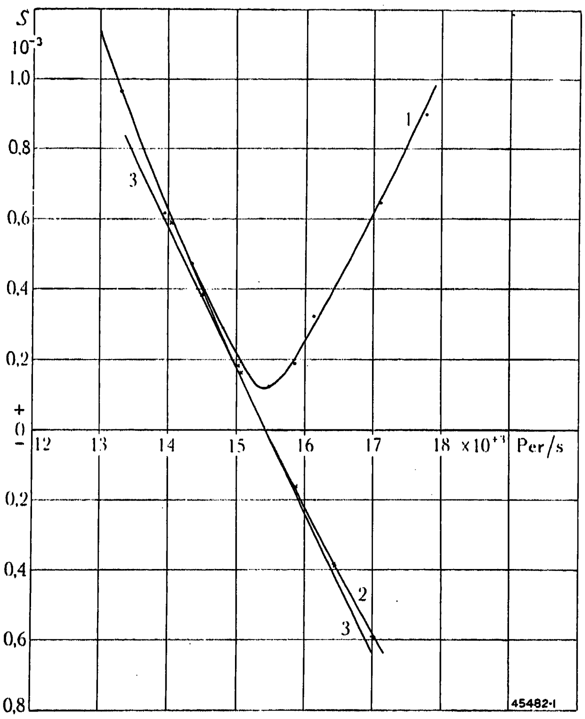


Fig. 5. — Graphic determination of the natural frequency, of the amplitude and of the damping from the measured admittance curve.

1. Admittance curve $|Y(j\omega)|$
2. Auxiliary curve deduced from 1: $\sqrt{|Y(j\omega)|^2 - |Y(j\omega_k)|^2}$
3. Tangent to curve 2 at point of intersection with the abscissae axis

$\omega_k = 2\pi \cdot 15{,}400$ cycles. $|Y'(j\omega_k)| = 0{\cdot}0645 \cdot 10^{-6}$ Ss.

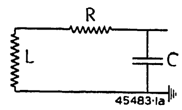
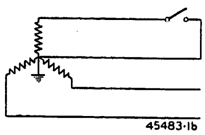
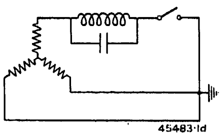
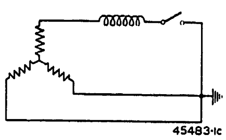
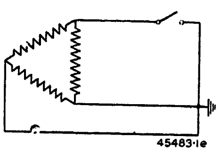
$$L_k = \frac{2}{|Y'(j\omega_k)|\,\omega_k^2} = 3{\cdot}31 \text{ mH}$$

$$\alpha_k = \frac{|Y(j\omega_k)|}{|Y'(j\omega_k)|} = 1780 \text{ s}^{-1}$$

VII. SUMMARY.

A method has been developed allowing of determining the behaviour of the recovery voltage, without making short-circuit tests. To this end, the admittance of the system, seen from the breaker terminals, in function of the frequency, must be measured. A simple calculation then allows of determining the frequencies of the various natural oscillations of the recovery voltage, their initial amplitudes and their

TABLE I.

Diagramme		ω_k s^{-1}	Amplitude %	L_k [1] mH	$L = \Sigma L_k$ [1] mH	α_k [1] s^{-1}
	High-frequency method	96,800	100·0	3·31	3·31	1,780
	Calculation	91,700	100·0	—	—	1,730
	Measurements with the cathode-ray oscillograph	—	—	—	—	—
$L = 3.52 \cdot 10^{-3}$ H $C = 0.033$ μF $R = 12.2\Omega$	Short-circuit measurements	—	—	—	3·52	—
	High-frequency method	132,000 168,000	61·3 38·7	0·212 0·134	0·346	7,500 12,750
	Calculation	129,500 164,000	—	—	—	—
	Measurements with the cathode-ray oscillograph	—	—	—	—	—
	Short-circuit measurements	—	—	—	0·318	—
	High-frequency method	96,400 199,000	95·0 5·0	0·725 0·039	0·764	6,300 11,150
	Calculation	96,800 280,000	95·7 4·3	—	—	—
	Measurements with the cathode-ray oscillograph	83,000 —	100·0 —	—	—	6,100 —
	Short-circuit measurements	—	—	—	0·796	—
	High-frequency method	92,400 135,000 272,000	75·0 24·4 0·6	2·52 0·82 0·02	3·36	2,900 14,400 55,000
	Calculation	87,000 149,000 —	86·0 14·0 —	—	—	—
	Measurements with the cathode-ray oscillograph	90,000 — —	—	—	—	2,200 — —
	Short-circuit measurements	—	—	—	3·34	—
	High-frequency method	149,000	100·0	0·193	0·193	17,200
	Calculation	175,000	100·0	—	—	—
	Measurements with the cathode-ray oscillograph	147,500	100·0	—	—	—
	Short-circuit measurements	—	—	—	0·191	—

[1] Explanation see the foregoing section.

damping coefficients. Even the short-circuit reactance can be determined from this high-frequency measurements.

This method gives the behaviour of the recovery voltage as dictated by conditions on the system, i. e. when an "ideal" breaker is used. It is, above all, a great advantage that the method gives the various natural harmonics separately, while the cathode-ray oscillographic records of short-circuit ruptures generally cannot be subdivided into the various natural frequencies.

(MS 554) P. Fourmarier. J. K. Brown. (Mo.)

STEAM FROM STANDARD CONDENSING TURBINES WITH SEMI-AUTOMATIC REGULATION OF THE EXTRACTED STEAM FOR HEATING PURPOSES.

Decimal index 621. 186. 89 : 621. 165. 169.

THE thermal superiority inherent to extraction-turbine operation, is due to the utilization, for heating purposes, of a portion of the steam which, primarily, has produced mechanical power in the high-pressure part of the turbine. Thus, the heat requisite to generate 1 kg of steam from water, and which amounts to about 515 calories at 3·5 at abs pressure is utilized and is not, simply, lost to the cooling water.

The blading of an extraction turbine of Brown Boveri design consists of two parts separated by a diaphragm. After it has passed through the high-pressure part of the extraction turbine, the total amount of steam is withdrawn from the turbine cylinder and part of it is extracted and utilized for heating. That part of the steam requisite to develop the remaining deficiency in power, and which cannot be utilized for heating purposes, is passed through a valve, generally termed "extraction pressure regulating valve", and flows through the low-pressure part of the turbine, after which it is, finally, condensed in the condenser. The extraction-pressure regulating valve, in front of the low-pressure part, maintains the pressure of the heating steam at a constant value.

There are cases, however, in which it is not necessary that the pressure of the heating steam should be kept constant, at all, and also where the amount of steam extracted for heating purposes plays only a small part, as compared to the total amount of steam flowing through the turbine. In such cases, it is possible to utilize the less expensive and standard type of condensing turbine, the latter being always provided with one, or with several, tapping (bleeding) points, the steam flow from which is not regulated. As long as the steam pressure at a tapping point without regulation is higher than the heating steam pressure requirements, the heating steam can be tapped from a standard turbine having neither diaphragm nor extraction-pressure regulating valve and it can then be throttled down to whatever pressure is necessary for the heating apparatus, in throttle valves. As the load on the turbine decreases, the pressure at the tapping point drops below the requisite value. When this occurs, the heating system is supplied with steam from the live steam main through a live steam reducing valve while the steam pipe from the tapped point is closed off from the turbine by a non-return valve.

The standard Brown Boveri single-cylinder turbines, running straight condensing, for outputs up to 10,000 kW are, always, provided with two taps below the cylinder, from which steam can be taken, mostly for the heating of the boiler feed-water. One of these tapping points is located behind the impulse wheel, the other in the middle of the reaction blading. Single-cylinder turbines for over 10,000 kW are provided with three tapping points, two-cylinder turbines having three to four and three-cylinder turbines four to five. The pressure of the steam at these tapping

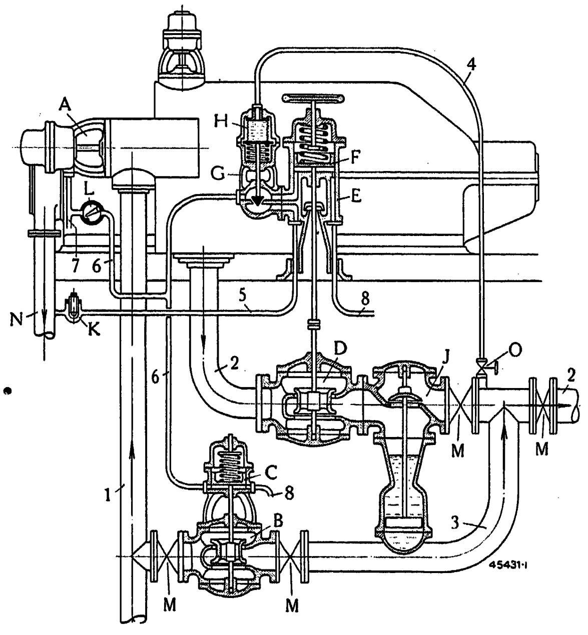


Fig. 1. — Governing system of standard Brown Boveri condensing turbine with semi-automatic regulation of the process steam.

A. Quick-acting closing valve.
B. Live-steam reducing valve.
C. Servo-motor piston of B.
D. Throttling valve.
E. Control for D.
F. Piston for E.
G. Pressure regulator.
H. Diaphragm for G.
J. Non-return valve.
K. Adjustment screw.
L. Non-return disc.
M. Valve.
N. Pressure branch of oil pump.
O. Isolating valve for the steam actuating the pressure regulator.
1. Live-steam main.
2. Tapping main.
3. Reduced-steam auxiliary main.
4. Steam connection to G.
5. Oil-pump delivery pipe.
6. Oil supply from B to G to L.
7. To starting and tripping gear.
8. Oil-outlet pipe to storage tank.

points varies proportionally to the total amount of steam flowing through the turbine. If, for example, there is available at the two tapping points a pressure of 4 and 1 kg/cm² abs, respectively, under full-load, in a single-cylinder turbine, these pressures would be reduced to somewhat more than $^1/_4$ of their full-load values if the load dropped to $^1/_4$.

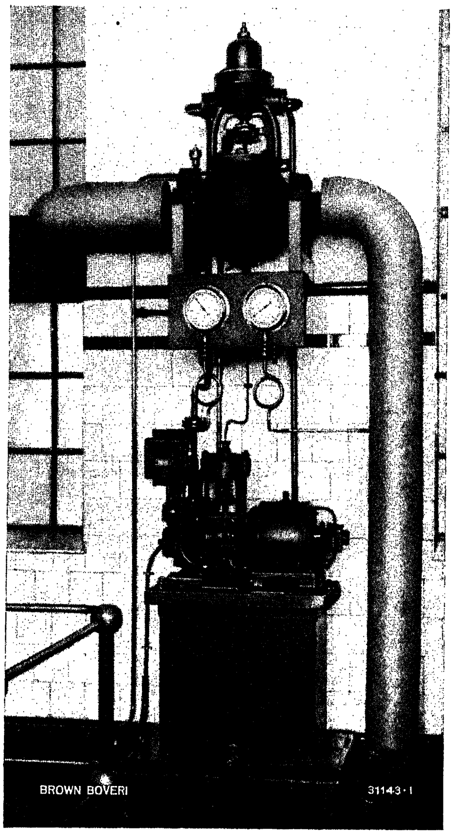


Fig. 2. — Thermostat regulation with oil-governed regulating valve.

For a steam-heating plant for which, usually, a steam pressure of 2 kg/cm² abs suffices, this being also the case for an air conditioning or hot-water heating plant in buildings, it is not necessary to maintain the pressure at the tapping point constant by means of an automatic pressure-regulating device on the turbine. In the case of a hot-water heating plant, for example, the heating up of the water, in the cold season, to about 90 ° C is necessary and up to about 60 ° C in the Spring and Autumn, therefore, a steam pressure of less than 1 kg/cm² abs suffices. Generally speaking, there is always sufficient pressure at the tapping point without special pressure regulation even when the turbine is under partial load. An adjustable regulation by thermostat, according to heating requirements, can be used which throttles down the heating steam at the point where it is used and maintains the necessary temperature of the hot water either in a storage tank or in a heat-distribution system.

Thermostat regulation consists of a metal-diaphragm thermostat which controls the oil-governed steam reducing valve through the agency of an oil-pressure relay, the former controlling the flow of process steam into the hot-water heater.

For the periods of very low turbine load, that is to say when there is not sufficient pressure available at the tapping points, a live-steam reducing valve must be provided, which throttles down the live steam to the desired heating-steam pressure. This live-steam reducing valve is also oil-governed. The necessary oil under pressure is taken from the governing-oil system of the turbine. In this case the governing diagram (Fig. 1) given here is valid, which is that of a standard condensing turbine with semi-automatic regulation of the process steam.

Generally, too high heating-steam pressures are specified for process steam in industrial plants, instead of the pressures which practice has shown to suffice. It should be born in mind that the further the steam used for heating can be allowed to expand in the turbine, the greater will be the output of the steam working in the high-pressure part of the turbine and, correspondingly, the higher the overall thermal efficiency of the plant.

The most frequent applications of turbines with tapping points, without extraction steam-pressure regulation, are to be found in evaporating and feed-water heating plants in power stations. It is avantageous to connect up the evaporator to a tapping point on the turbine at which a pressure of about 3 kg/cm² abs pertains when the turbine is under full load. The vapours from the evaporator, which contain about 640 kcal, are condensed in a feed-water heater, being cooled by the condensate which is delivered by the main condensate pump from the surface condenser. With this arrangement, if the vapours leave the evaporator at a temperature of about 100° C, the condensate which leaves the condenser at, say, 35° C, can only be warmed up to about 95° C in the vapour condenser. As the output of the turbine drops, the amount of vapours condensed in the vapour condenser drops as well, which, however, is of no importance for ordinary power-house service, as the steam consumption has also dropped and the same percentage of make-up water can be obtained, compared to the steam consumption at each partial load. However, it is also possible to connect the evaporator to the main surface condenser, so that the vapours from the evaporator are condensed in the condenser itself. The amount of make-up water can be, thus, considerably increased, because there is a much greater temperature drop available for the evaporator (about 80 instead of about 35° C) in this case, also. A thorough deaeration of the make-up water is assured, by means of the standard hydraulic air ejector, in the main condenser. This solution, however, has the disadvantage that the heat contained in the vapours is lost in the main condenser and, for this reason, the process is not recommendable for ordinary service. In most cases, a second feed-water heater is provided connected

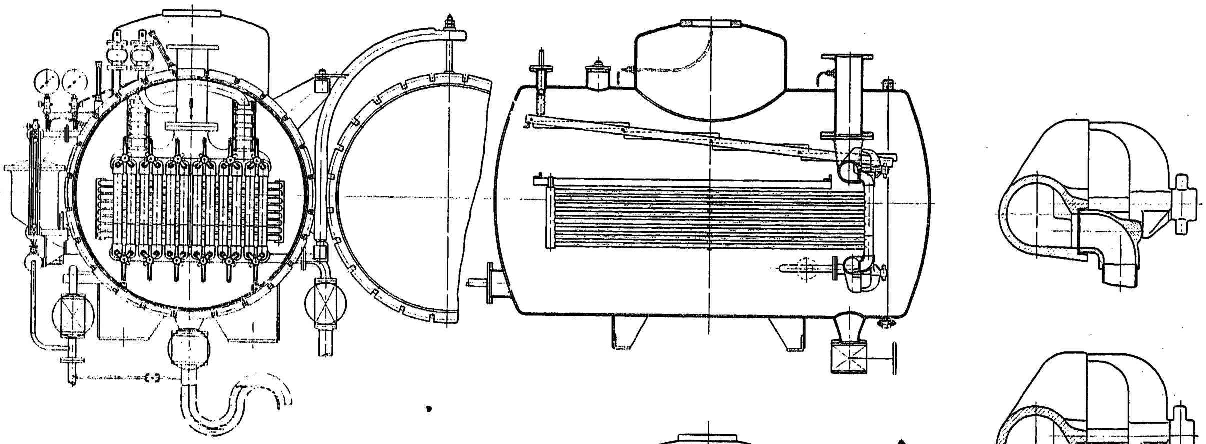
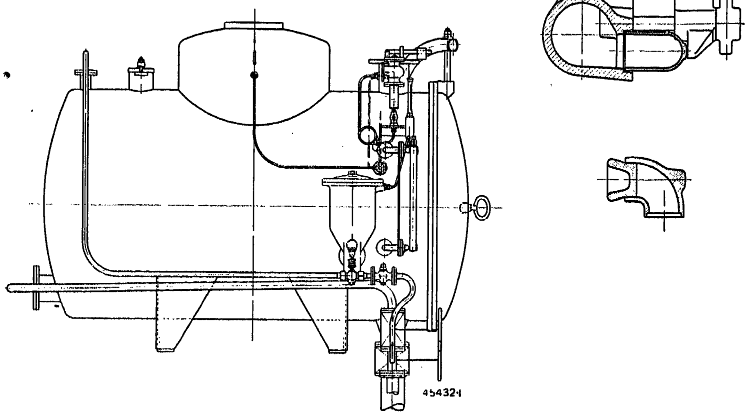



Fig. 3. — Section of an evaporator of Brown Boveri design.

to the same tapping point as the evaporator. A definite final temperature of the feed water can be attained with this feed-water heater, corresponding to whatever the tapped-steam pressure happens to be, at given loads of the main turbine.

The main condensate pump must be designed for a sufficient delivery head, in order to overcome the friction resistances in the feed-water heaters and to deliver the condensate to the entirely-enclosed feed-water container. The drain water from the feed-water heaters has also got to be delivered to the entirely enclosed feed-water container, through the agency of a special condensate pump driven by an electric motor. It is only in small plants that it is admissible to drain the feed-water heater into the main condenser, which, again, has the disadvantage of loosing in the condenser the heat contained in the drain water of the feed-water heater.

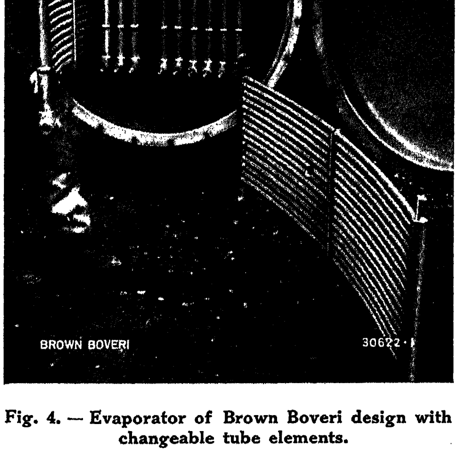


Fig. 4. — Evaporator of Brown Boveri design with changeable tube elements.

In the case of big two-cylinder and three-cylinder turbines, three and even four feed-water heaters are put in, in order to heat up the condensate to a temperature of 60—70 % of that of the saturated steam.

The heating up of the feed water to 60—70 % of the temperature of the saturated steam means, however, that no, or only a very small, economiser is used for the boiler plant but that air heaters of the combustion air for the firing of the boilers, must be used, so as to utilize the heat contained in the flue gases. In this case, a gain in heat up to about 7—8 % is attained as compared to boiler operation without feed-water heating but using an economiser, only.

For Velox steam generators, which are equipped with economisers a heating up of the feed water to 80—90° C is advisable, as it allows of gaining about 5 % in heat consumption without affecting the boiler efficiency.

The evaporators of Brown Boveri design are built according to the section drawings and photographs shown in Figs. 3 and 4.

The brine from the evaporator can be withdrawn during service. The evaporator has a high steam-dome, to prevent the vapours from carrying along raw water with them. Regulation of the make-up raw water is carried out by means of a cock actuated by a float in the evaporator. The delivery of the make-up of raw water takes place under pressure from an avail-

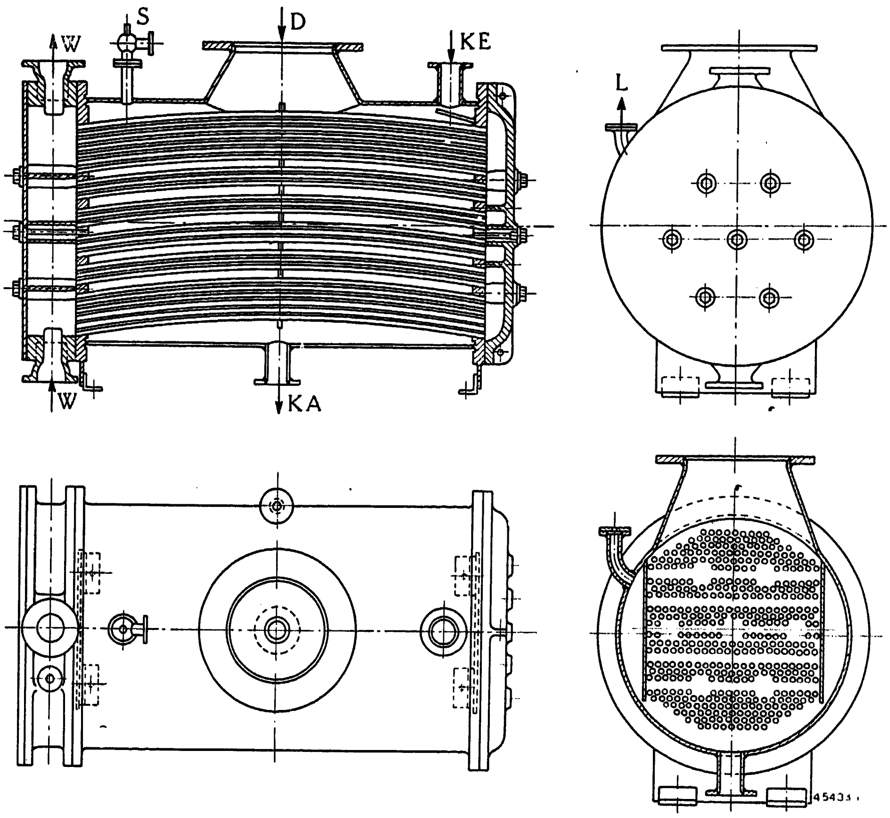


Fig. 5. — Section of feed-water heater of Brown Boveri design.
D. Steam. K. A. Condensate outlet. S. Safety valve.
K. E. Condensate inlet. L. Air. W. Feed-water.

able water pipe or raw-water pump. The evaporators are composed of containers of steel, of the steam-distributing pipe and the condensate collecting pipe of cast iron, the heating pipes of copper. In the Brown Boveri evaporators, the heating pipes can be taken out in sections for cleaning purposes, which is considered to be of great advantage.

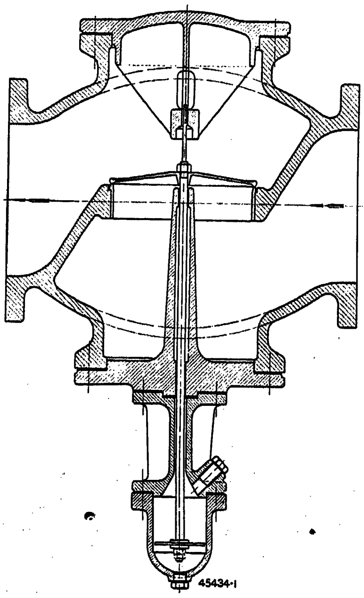


Fig. 6. — Section of non-return valve at tapping point on a turbine.

Each evaporator has the following accessories:— the raw-water float regulation, the draining valve, the condensate valve, the safety valve for the tapped steam entering and for the vapours flowing off, the water-level indicator, the thermometer for steam inflow and vapour outflow, a mano-vacuummeter for the tapped steam entering and for the vapours flowing off.

The steam pipe between the tapping point on the turbine and the evaporator is equipped with a hand-operated isolating valve and a non-return valve, to prevent water from the evaporator penetrating into the turbine.

In many cases, it is advisable to provide for a preliminary chemical cleaning with heating up of the raw water by tapped steam, which causes scale and, mainly, muddy deposit to be eliminated.

Section drawing Fig. 5 shows the design of the feed-water heaters. The bodies are built up of steel plates welded together. The cooling tubes are composed of brass or cupro-nickel and are expanded into the mild-steel tube plates. They have a diameter of 13/15 mm. In order to allow of expansion under temperature differences, these tubes are slightly bent before expansion into the tube plates. The following accessories go with the feed-water heaters:— a safety valve on the steam side and on the water side, as

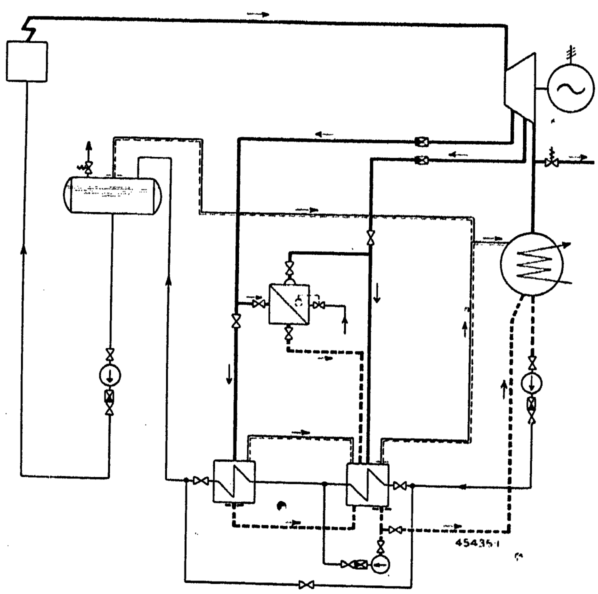


Fig. 8. — Standard diagram of evaporating and feed-water heating plant of Brown Boveri design.

= Stop valve.
= Non-return valve.
= Exhaust-valve to atmosphere.
= Float regulation valve for raw water.
= Diaphragm.
= Pipe line.
= Drainage pipe.
= Condensate and boiler feed-water pipe.
= Air exhausting pipe.

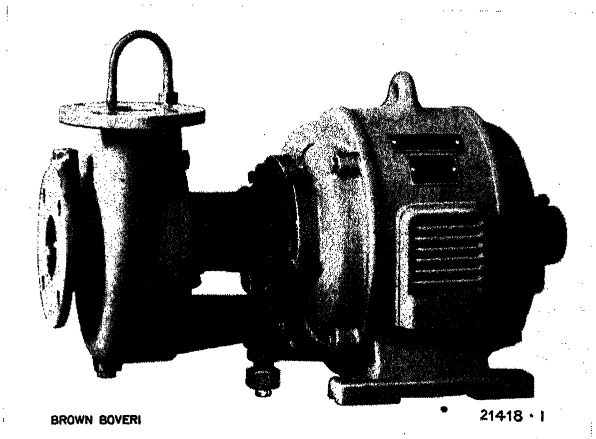


Fig. 7. — Condensate pump driven by electric motor.

well as a thermometer at the outlet end to the main condensate pipe. The thermometers allow of exact supervision of the working of the feed-water heating plant. There is a deaerating pipe connecting the feed-water heaters to the condenser to allow of carrying away whatever air is given off in the former.

To produce the amount of make-up water necessary at any moment, 10 % more steam tapped must be reckoned with, because the raw water, from which the vapour is formed, must also be heated up to the temperature of the evaporator. In an efficiently-managed power station, working straight condensing, experience shows that only 1 to 3 % boiler make-up water is necessary, reckoned on the momentary steam requirements. But even if 5% of the momentary steam delivery has to be evaporated, the ordinary evaporating and feed-water heating plant, according to the diagrams shown (Fig. 8), suffices.

In order to attain very big-evaporated quantities, such as are required in power stations attached to industrial works, where a great part of the process steam is used for chemical purposes and lost, two or three evaporators can be connected in series (double or triple effect).

The evaporating plant always delivers boiler make-up feed water of very suitable quality free of salts and with very little oxygen, such as is indispensable in modern high-pressure boilers.

(MS 540) *G. Leidig. (Mo.)*

NOTES.

Switchboxes with retarded low-voltage tripping device.

Decimal index 621.316.577.

THE low-voltage tripping device of switchboxes acts as soon as the supply voltage has dropped to a definite minimum value or has failed altogether. However right it may be that the circuit breaker should be caused to trip, in such cases, it is often very undesirable, in a great number of plants, that every — and even the briefest — drop of voltage should cause the complete immobilization of the plant.

Fig. 1 shows a motor-protection switchbox of the usual design, in which the low-volt tripping device is provided with a certain *retardation,* or lag, which can be adjusted to between the values 0 and 7 seconds. When the voltage drops to an insufficient value, the armature 1 of the low-volt electro-magnet does not fall instantaneously but causes a retarding mechanism 2 to run which frees the movement only after the time lag set to and releases the catch of the switch, causing the latter to open. The time lag desired is set by means of a guide piece 3, this both precisely and easily, when the switchbox cover is open.

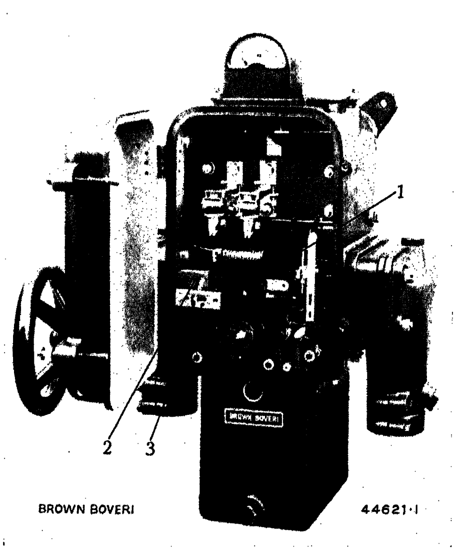


Fig. 1. — Motor protection switch, Type MB 8h ab, for 250 A rated current with built in time retardation for the low-voltage tripping device.

A time lag of as much as seven seconds should, however, only be set for after careful consideration of prevailing conditions. The following paragraph should be of some assistance in the choice of the most advantageous time-lag setting.

Motors with squirrel-cage rotors for straight switching in do not require, for themselves alone, any low-voltage tripping device, because, when the voltage builds up again after short or long interruptions, they start running again, as they do under ordinary starting conditions. On the other hand, it is very necessary to have some protection against arbitrary restarting as a protection of the operators in the plant and of the service. Certain power-supply companies definitely specify that motors from a determined output upward must be equipped with switchboxes having low-voltage tripping. Whether there should be a time lag feature incorporated to prevent tripping under brief supply disturbances is a question for itself. Due to the simplicity of the manipulation of these controls, it is, really, of no importance if the switches trip, now and again, and have to be reclosed. The same applies also, generally, to motors with centrifugal starters.

Conditions are very different in the case of *motors with squirrel-cage rotors and star-delta switchboxes.* The star-delta switch is used in plants where it is desirable to reduce the starting-current surge considerably. It fulfills this requirement only if the switch is laid over from the starting to the running position when the motor is nearly at its full-rated speed. Every faulty switching operation causes current surges which affect the very object of this type of starting considerably[1]. As star-delta starting is generally used for machines which start up easily, it must be reckoned with that the motor under its rated load will quickly come to a stop even under the effect of a brief failure in the voltage, so that a big current surge can be expected when the voltage builds up again. Strictly speaking, switches of this type should *always* have low-voltage tripping devices to prevent the

[1] See The Brown Boveri Review, year 1935, No. 12:— "Star-delta switches with thermal releases, for current ratings of 64 to 400 A and a voltage rating of 500 V."

motor, which may still be rotating slowly, or may have stopped, being put under voltage again in the delta connection and the system being subjected to a starting-current surge. For the same reasons, in most cases it would be a mistake to provide the star-delta switches with a time-lag feature on the low-voltage tripping device.

In the case of *motors with slip rings, shunt commutator motors* and others having a special starter, or which are started by brush displacement or the like, the low-voltage tripping device is as essential as for star-delta switches. On the other hand, it will frequently happen that a certain time lag in the trip is very desirable. Especially in the case of drives incorporating big kinetic energy, the time lag can be considerably accentuated without danger of trouble, if the voltage builds up within the time set to. Nevertheless, in estimating the time lag, one must not deduce erroneous conclusions from the big masses incorporated in some industrial machines. *Slow-running* heavy masses do not incorporate big kinetic energies; high speed is of far greater importance. Thus, a heavy tube mill, driven at only about 20 r. p. m., stops far quicker — and, thus, must have a much shorter time-lag trip — than a beating mill, for example, operated at 4000 r. p. m., although the mass of the latter is far smaller. In any case, a simple test suffices to determine the time lag which should be set to.

It will be clear that it depends entirely on the type of motor and service conditions, whether the motor-protection switch should be equipped with a retarded low-voltage tripping device or not. To what degree the retarding of the trip may be useful in the case of *switches for groups of motors or station switches*, also depends, primarily, on the nature of service and on the motors connected up. The considerations enumerated here for the utilization of the retarted tripping device on motors should be valid here, in principle.

The retardation of up to seven seconds allowed for the Brown Boveri switches is, as said before, very ample and should only be made full use of in exceptional cases. In the majority of cases, a retardation of a half to two seconds should be sufficient.

(MS 553) *S. Hopferwieser. (Mo.)*

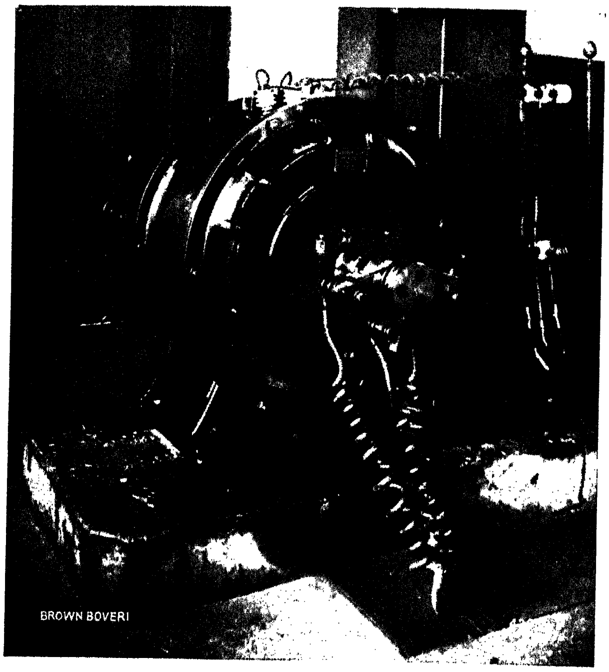


Fig. 1. — Lourdes-Pic au Grand-Jer funicular railway.
Two-phase, A. C. motor, 50 kW, 3100 V, 45 cycles, built in 1899.

Service reliability of Brown Boveri material.

Decimal index 6 (009·2) : 625. 52.

SINCE the year 1900, a Brown Boveri, two-phase motor of about 50 kW rated output at 675 r. p. m., 3100 V terminal voltage and 45 cycles has been running, practically continuously, to drive the Lourdes-Pic au Grand-Jer funicular railway in France. A stand-by motor purchased at a later date by the railway management has only been called on to work for a short period on very infrequent occasions. This was when the stator coils of the old motor had to be changed, having been damaged by lightning. The carrying capacity of the line was considerably increased in the year 1925 by increasing the running speed of the coaches from 1·2 to 1·5 m/s and the passenger capacity of the coaches from 50 to 60. No change whatsoever had to be made to the electrical equipment in order to meet these new service conditions. Fig. 1 shows the motor, with the primitive connecting devices of that period, mounted in the engine room of the funicular railway. There seems little doubt that this motor will continue to fulfill all requirements for a long time to come and despite the increased requirements and frequent overload peaks inherent to funicular railway service which have to be overcome. The clients write as follows on the subject of the motor first delivered: —

"The motor of more modern design which serves as a stand-by to the older one, has only been put into service five or six times and then only for short periods, just as long as was necessary to replace one or two stator coils in closed slots which had been damaged by lightning. The stator was completely rewound once; practically, the motor as originally delivered has been running without any trouble developing from July 1900 to July 1936 that is for 36 years."

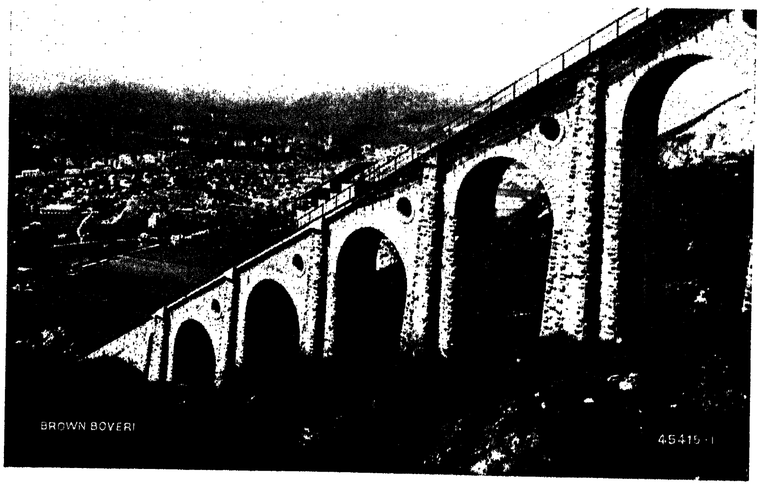


Fig. 2. — Part view of Lourdes-Pic au Grand-Jer funicular railway.
Lourdes in the background.

(MS 536) *E. Hugentobler. (Mo.)*

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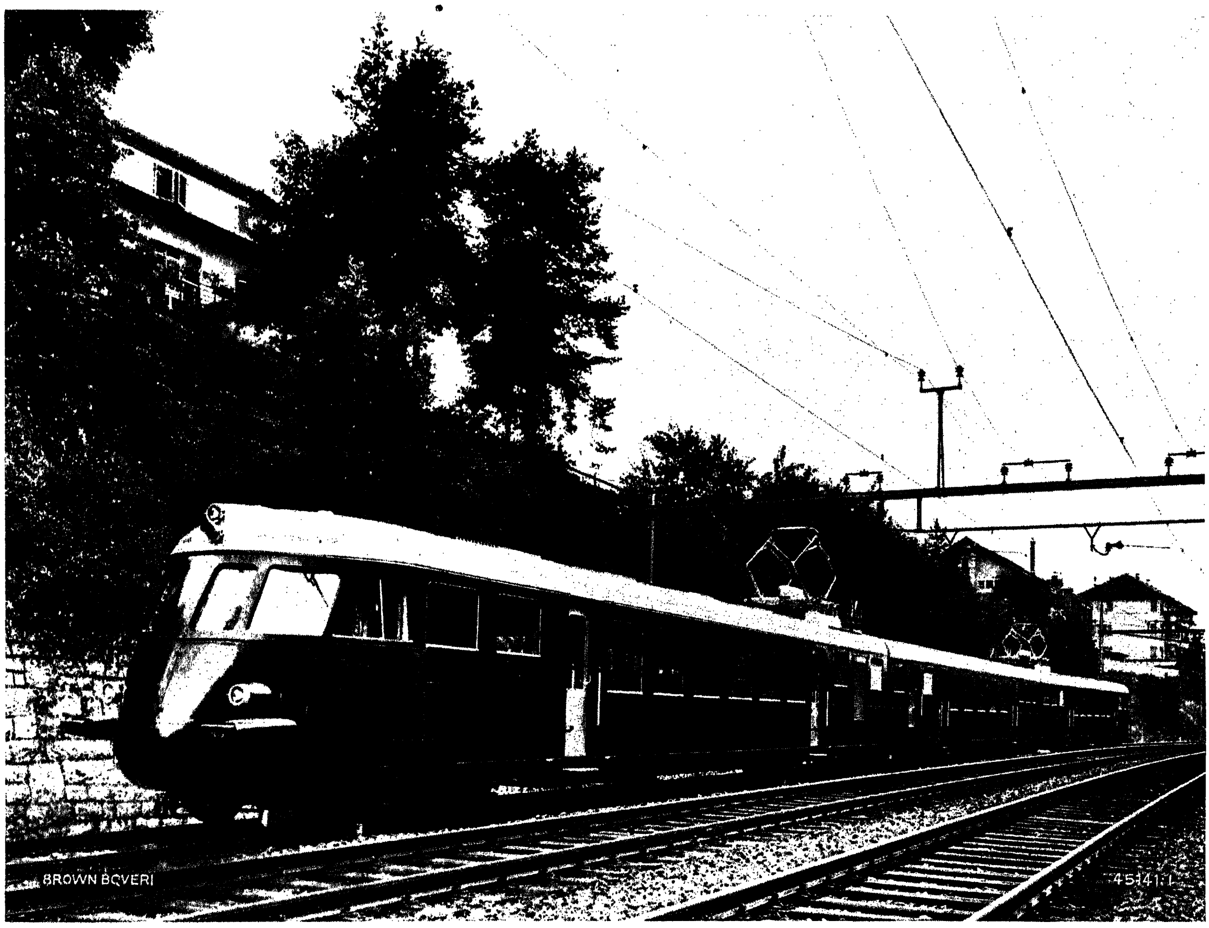


HIGH-SPEED MOTOR-COACH TRAIN RE 8/12 No. 502 OF THE SWISS FEDERAL RAILWAYS.
Contact-wire voltage 15,000 V, $16^{2}/_{3}$ Hz.

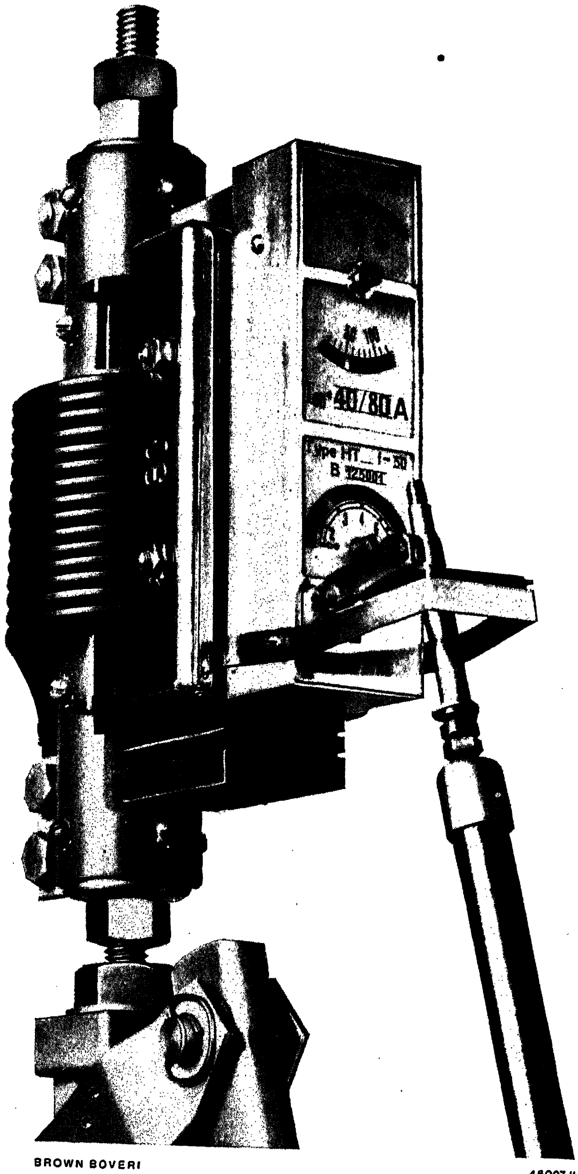
CONTENTS:

Printed in Switzerland

THERMAL PRIMARY RELAY
TYPE HT

The **first** relay to duplicate faithfully the thermal characteristic of the object protected.

With time constants of 15, 30 or 45 minutes.



A high-voltage overload relay of exceptional adaptability.

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIV SEPTEMBER, 1937 No. 9

THE CONTROL OF THE HIGH-SPEED MOTOR-COACH TRAINS RE 8/12 Nos. 501 AND 502 OF THE SWISS FEDERAL RAILWAYS.

Decimal index 621. 337. 1 (494).

FROM the point of view of technical operation, alone, the introduction of the high-speed motor coach to the system of the Swiss Federal Railways has widened the field of traction experience and available knowledge. One important fact determined was that the travelling speed of these light coaches on curves, under given line conditions, could be greater than that of locomotives. As an innovation, the time tables worked out for the first high-speed motor coaches were based on considerably shorter stops than heretofore. This quickening in travelling time was speedily appreciated by the public and exercised an influence on the time tables of other coaches and trains. Very notable progress was made in shortening the starting-up period. This, and the stepping up of the maximum running speed from 90 and 100 km/h to 125 km/h, caused a very welcome upwards correction of the average travelling speed. It is, thus, comprehensible that these mobile coaches soon proved both economical to run and popular with travellers; indeed, there is hardly another of the many improvements introduced to the Swiss railways which was so quick to gain and hold the favour of passengers. While the utilization of the available seating capacity in other types of train often leaves much to be desired, this cannot be said of the high-speed motor coach. On many line sections, the need was soon felt of increasing the passenger-carrying capacity of these light coaches. As, at the same time, at least one compartment had to be reserved for second-class travellers and room reserved for luggage and postal facilities, the Swiss Federal Railways decided to bridge the intermediate step of a two-unit train and to take up immediately the building of three-unit trains. As a very general utilization of the two trains ordered was one of the most important aims, the requirements made on the machinery and on starting up conditions were such that the train could be used in express or in local service, as desired.

Of the three units coupled together, only the end ones have driving motors. As there is no room here for a general description of the whole train, the main data, only, is given along with a short description of the progress made in the electrical equipment.

Current supply	15,000 V A. C., 16 $^2/_3$ Hz
Gauge	standard
Maximum speed	150 km/h
Diameter of driving and running wheels	900 mm
Ratio	1 : 2·64
Total length of train	68·7 m
Number of passengers seated	30 in 2nd class 192 in 3rd class (including flap seats)

Total number of passengers seated 222 (incl. flap seats)
Available area of the luggage compartment about 10 m².

Weight of mechanical part of train	77 t
Weight of electrical part of train	40 t
Weight of equipment	0·5 t
	117·5 t
Load carried when full	23·2 t
Total weight of train	140·7 t

The total one-hour power rating measured on the motor shaft is $8 \times 290 = 2320$ H. P. at 115 km/h running speed. The total continuous power rating measured on the motor shaft is $8 \times 248 = 1984$ H. P. at 125 km/h travelling speed.

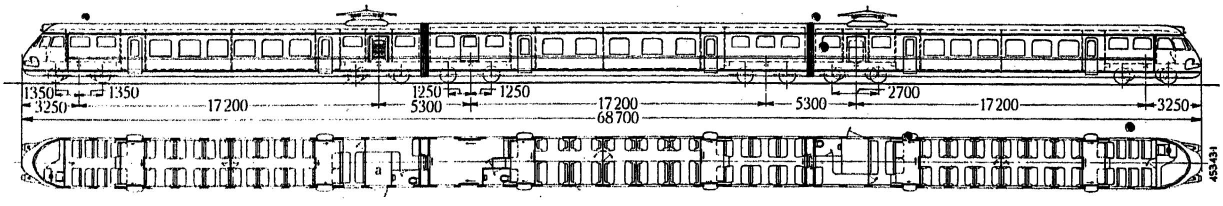


Fig. 1. — Elevation and plan of high-speed motor-coach train. Mechanical part by Swiss Locomotive and Machine Works, Winterthur.
a. Room for transformers and apparatus in end coaches.

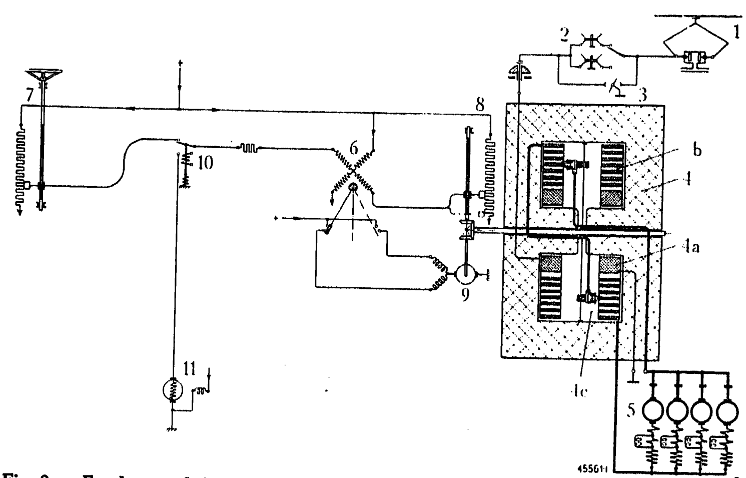


Fig. 2. — Fundamental diagram of connections for the transformer for smooth voltage regulation with the electric motor control belonging thereto.

1. Pantograph type of current collector.
2. Roof fuse of the switching-over type.
3. Earthing switch.
4. Transformer.
4a. Primary winding.
4b. Secondary winding.
4c. Current collecting in secondary winding.
5. Driving motors.
6. Polarized relay.
7. Potentiometer in master controller.
8. Potentiometer on drive of transformer regulation.
9. Control motor.
10. Change-over relay.
11. Small dynamo driven by coach wheels.

The weight per running metre for the empty train is 1·7 t/m.

The weight per seat of the empty train is 530 kg.

As an interesting innovation in the electrical equipment of both high-speed trains, mention should be made of the regulation of the travelling speed by a newly-developed system of control.

On A. C. vehicles, it was generally usual, up till to-day, to bring about changes of voltage across the motor terminals through the agency of taps on the transformer winding, which were stepped more or less closely from each other. The unavoidable interruption of current supply to the motors for a short space of time, inherent to this system is bridged over by a switching combination of choke coils or damping resistances which calls for a considerable number of on-load contactors. Despite the bridging of the steps there are, of course, unavoidable current surges in the motor supply the intensity of which depends on the size of the step.

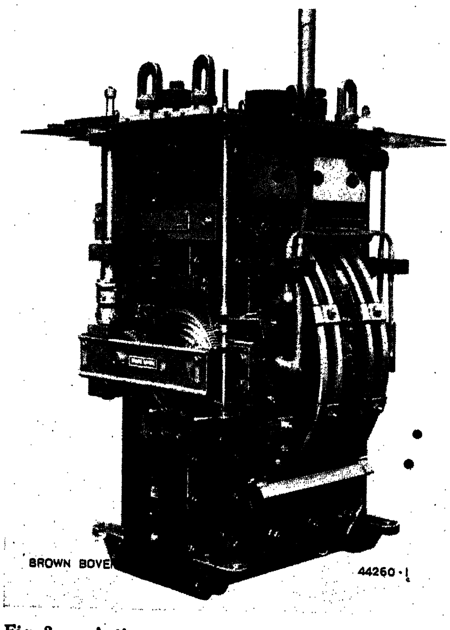


Fig. 3. — Active part of transformer, continuous output 510 kVA.

Abandoning this method of switching, which has been used for years, Brown Boveri has designed and built a traction transformer which allows of absolutely continuous and smooth (without steps) current collecting over the whole voltage range of the secondary winding. As the diagram of Fig. 2 shows, the primary winding is wound on to the core of the transformer and the secondary winding is wound on, spirally, over it and concentrically to it. There are rolling contacts which run on the bare edge surface of the secondary winding and collect the current. These roller contacts are guided by the winding and are actuated by a motor-driven carrier piece.

The great simplification attained by the elimination of contactors and step-transition choke coils is very apparent. The noise accompanying switching operations and the burning away of sparking contacts are, both, entirely eliminated along with elimination of the contactors.

Experience gathered from service on the big Gothard-line locomotives showed that switching apparatus without interruption of current, lodged in oil-immersed transformers, worked well under oil and called for practically no upkeep in service. In these locomotives, interruptions under oil on the 15,000-V side were carried out without interruption of current; despite this, the step switch is only overhauled every three years when the general overhaul of

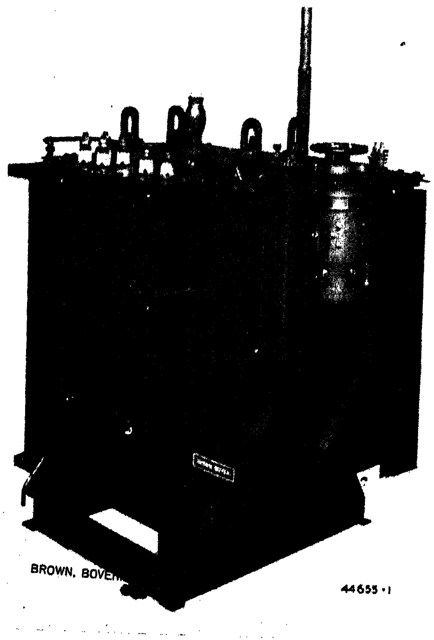


Fig. 4. — Transformer with cooling pockets for outside ventilation, driving motor of voltage regulation and potentiometer for control.

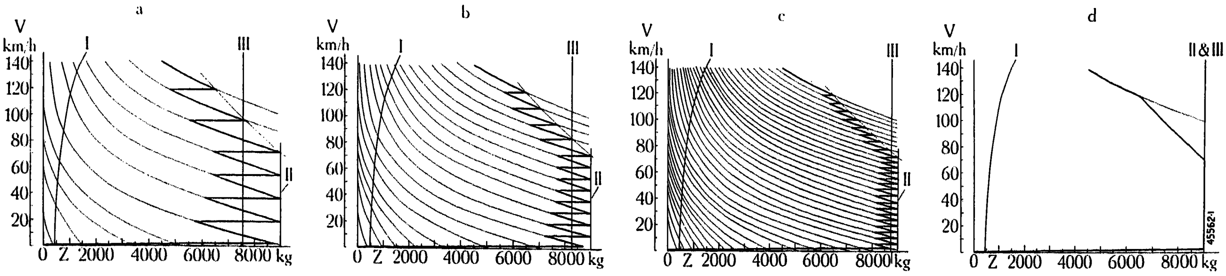


Fig. 5. — Curves for speed, for control system with from 11 up to an unlimited number of starting steps.

a. Diagram with 11 starting steps on transformer.
b. Diagram with 20 starting steps on transformer.
c. Diagram with 39 starting steps on transformer.
d. Diagram with smooth (no steps) current collection.

The following apply to the diagrams:—
I. Running resistance on level.
II. Max. allowable traction effort of driving motors.
III. Average traction effort.
Z. Total tractive effort in kg at wheel tread.
V. Running speed in km/h.

the locomotive is carried out. Therefore, there are no charges incurred for upkeep during this long interval of time.

However, the new transformer (Figs. 3 and 4) apart from its switching qualities has other valuable properties for traction purposes. Thanks to the smooth voltage regulation there are no shocks whatever when the train starts or when its speed is changed.

Figs. 5a to 5d show four speed diagrams for the high-speed motor-coach train, first under the assumption that the transformer has different numbers of taps. It will be understood, at once, on looking at these diagrams, that the starting impulses and starting current surges are reduced by increasing the number of taps. The accelerating impulses correspond in the diagram (Fig. 5a) to about 0·2 m/s^2 and are reduced to 0·16, according to Fig. 5b and to about 0·07 m/s^2, according to Fig. 5c, while they are, practically, suppressed altogether with the smooth speed regulation without steps as shown in Fig. 5d. It is the average starting traction effort III which is valid for the calculation of the starting acceleration of the train; this value is always being displaced further towards the right, in Figs. 5a—c, as the number of steps on the transformer increases and leads to a correspondingly numeral improvement of the average starting acceleration. The latter is 0·46, 0·5, 0·53 m/s^2 referred to Figs. 5a—c. In smooth switching (without steps) according to Fig. 5d the vertical tractive-effort line which is valid for the average acceleration, coincides with the peak limit line; the starting acceleration attains a maximum of 0·63 m/s^2 in the example given. These figures are to be understood as applying to the starting period from 0 up to 70 km/h running speed. In the case of the high-speed motor-coach train, the adhesion conditions are very ample so that there is no danger of the wheels skidding under ordinary conditions. There are vehicles, however, in which the adhesion load is fully utilized, especially at starting. If, for example, the vertical line, drawn in at a traction pull of 9000 kg, according to Figs. 5a—d, were also the limit beyond which the wheels began to skid, the available average traction pull of Fig. 5a would have to be 7570 kg only, but in diagram 5d it would be 9000 kg, that is to say it would equal the peak-traction effort.

Owing to the fact that the voltage regulation is now no longer bound to any determined taps, but is a smooth continuous one, remote control of the voltage regulation becomes much simpler and assumes new forms. A polarized relay (Fig. 6), one coil of which is branched between two potentiometers while the other one is branched on the lighting battery, works on a change-over contact with recall spring. If the sliding contact on the potentiometer (Fig. 2) on the left is moved to the position indicated, through the switching forward of the master controller, the coil branched between the two potentiometers is supplied with current until the contact of the potentiometer (right) carried along by the carrier of the current collector on the transformer (starting position indicated dotted in diagram) has attained the same position. By this process, the voltage-regulation driving motor is controlled in the desired switching sense by the change-over switch of the polarized relay and, after attainment of the same voltage value on both potentiometers, the said motor is brought to rest again. If the sliding contact of the potentiometer in the master controller is again displaced, the current sense in one of the coils of the polarized relay changes again which causes the control motor to rotate in the corresponding sense. By a suitable choice of the gear ratio of the trans-

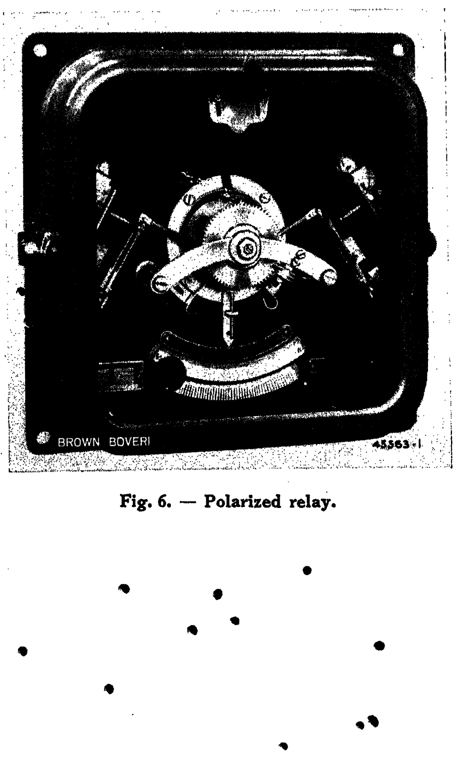


Fig. 6. — Polarized relay.

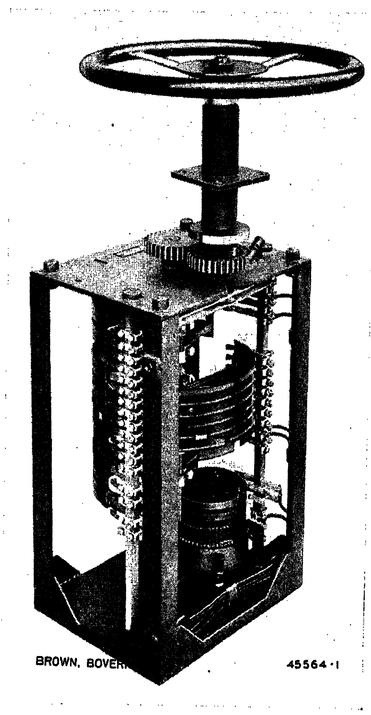


Fig. 7. — Master controller; for running service only the potentiometer, with the contacts belonging to it, seen on the right below, is used. All other contacts and slip rings are for the control of the short-circuit brake.

former drive, the handwheel of the master controller can be carried to its end position immediately, at starting. Without the driver having to do anything else, the voltage then increases progressively until the sliding contact on the potentiometer (right) again attains the level of the contact of the potentiometer (left.) To initiate instantaneous cutting out, the handwheel is brought to the zero position which immediately causes the driving-motor switch to be actuated; at the same time, the regulating coil of the polarized relay is switched over, by change-over relay 10 (Fig. 2) from the potentiometer in the master controller to a small dynamo 11 (Fig. 2) driven by a running wheel of the coach. The terminal voltage of the small dynamo changes proportionately to the running speed of the coach and also, consequently, changes the voltage of the transformer, through the action of the control motor of the said transformer, bringing it to a value which allows a reclosing of the driving motors at any moment without shock. In this way, not only is the number of transformer switchings considerably reduced but the readiness for switching service and the possibility of quick coach acceleration are increased. The ordinary switching-forward time is about 60 and in special cases 20 seconds. The latter figure also corresponds to the ordinary cutting-out time with closed driving-motor switch.

As in the case of the high-speed motor coaches of the Swiss Federal Railways, the electric short-circuit brake is not only used for retarding at stopping but also for lowering the running speed on curves and at points where slowing-down is necessary; in this case, as well, the small dynamo sees to it that the transformer voltage is such that switching in again can be carried out immediately at the running speed prevailing. If the master controller (Fig. 7) had only got to perform the duty of running control and not of braking control, which is still in steps, it would, practically, be only composed of the incoming current lead and a commutator-shaped potentiometer.

While it is generally necessary to have one conductor per tap in contactor-control gear, only two conductors passing through the whole train are necessary here, where, practically, the number of taps is unlimited as well as the number of remote-controlled coaches in the make-up of the train. One of these conductors can be done away with (Fig. 8) when the quick-switching (in 20 s), mentioned before, is not called for.

As there were three electrical-material manufacturers collaborating in the delivery of material for the two high-speed motor-coach trains, Brown Boveri had to renounce getting the order for the driving motors and drives, because they had already been entrusted with the delivery of the transformers and

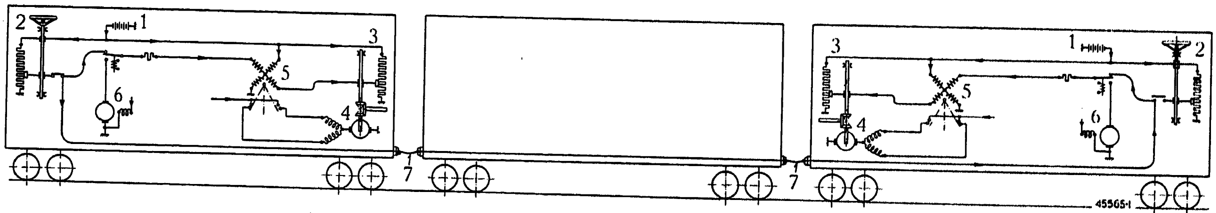


Fig. 8. — Fundamental diagram for remote control of transformers in both motor-coaches.

1. Lighting battery and control current.
2. Potentiometer in master controller.
3. Potentiometer on drive of transformer regulation.
4. Control motor.
5. Polarized relay.
6. Small dynamo.
7. Remote-control wire.

control gear. This was regrettable to them because it prevented them putting in the Brown Boveri sprung drive which has given such excellent results on seven express motor coaches of recent design.

It should be added that the Brown Boveri system of heating by air warmed by electricity and of summer-time ventilation is applied on the new trains. These equipments were completed by putting electrically-controlled flaps on the air-exhaust points of the air ducts. This means that each compartment is equipped with temperature regulation, individually and by means of thermostats.

As with the new express motor-coaches recently introduced, the development of these high-speed motor-coach trains is an example of the will and efforts of the Swiss Federal Railways to keep their rolling stock abreast of with modern progress.

(MS 570)

W. Lüthi. (Mo.)

THE ROSENKRANTZGATE STEAM POWER STATION OF THE OSLO ELECTRICITY WORKS. A VELOX PEAK-LOAD PLANT OF CONSIDERABLE OUTPUT.

(Continued and concluded from No. 8/37.)

Decimal index 621.311.22 (481).

THE MAIN TRANSFORMER.

The power from the generator is delivered through a transformer (built by another manufacturer) straight to the 30-kV system. Generator and transformer thus form a unit, which is why we mention it here, directly after the generator. It is built to the following conditions:—

Rated output at p. f. = 0·9 .	35,000 kVA
Service voltage on primary side	6,600 V
Service voltage on secondary side	30,000 V

We give no detailed description of this unit, here, but would say, however, that it has forced oil circulation and indirect cooling of the oil by sea water. There is a separate, electrically-driven pump set for the cooling which is connected to the suction branch of the cooling-water supply to the condensing plant, so that it is possible to use the transformer for other purposes, when the steam plant is not running. This is gone into, in more detail, at the end of the chapter: "The electric switching, regulating and protective devices for turbo-generator and main transformer".

THE SUPPLY AND TREATMENT OF THE FEED WATER.

Fig. 6 shows the circuit followed by the driving element water-steam. The condensate pump running drives the condensate through a single-stage preheating plant into an enclosed feed-water tank, deaerated by being connected to the condenser. The feed pumps (one of which is driven electrically and the other by a turbine, and each of which is dimensioned for the total output of both Velox steam generators) are supplied from this tank. Level conditions are so chosen that the proper working of the pumps is assured.

To-day, there are numerous, good methods of raw-water treatment available, so that very good boiler service can be attained, practically, for every case encountered in practice. This is also valid for the modern high-capacity boilers and the Velox is no exception. It should be stressed here again that the Velox is no more difficult to supply in this respect than any other type of boiler used in modern power stations. Mention may be made of the Velox plant installed since some years in a chemical works in Roumania and where conditions are such that all the condensate is lost, at certain times, so that 100 % feed-water treatment has to be resorted to. The available raw water contains a considerable amount of silicates and this does not affect continuous service of the Velox or subject the latter to choking up or boiler-scale formation, although the water has to be chemically treated. A report on this plant will be found in the April 1937 number of The Brown Boveri Review.

In the case of ordinary power-supplying plants, the condensate and boiler-water losses can be kept down, by a proper layout and efficient supervision. They are chiefly determined by the blowing-down process of the boiler, a necessary measure in order that the maximum allowable salt concentration in the boiler water, with regard to the danger of spurting, should not be exceeded; this maximum salt concentration corresponds to an alcalinity of 1000, usually. The lower the salt concentration in the boiler water, the dryer the steam generated will be and the possibility of the tubes of the superheater and the machines themselves getting salt-coated will be reduced in the same ratio. In principle, therefore, it is recommendable to do everything to keep down the alcalinity. As a matter of fact, it is known, to-day, that modern boilers can, usually, be operated without danger with very low alcalinity figures, of 100 and less, on condition that the feed water be subjected to an absolutely reliable degassing process.

The blow-down quantity is, on the one hand, naturally a function of the salt concentration allowed for, but, on the other hand, it depends on the amount of salt in the feed water that is to say on the previous treatment of the make-up water required, its quantity, as well as on the tightness of the condenser. As is known, it is sufficiently exactly determined by:—

$$L = \frac{S}{G - S} \times 100$$

where

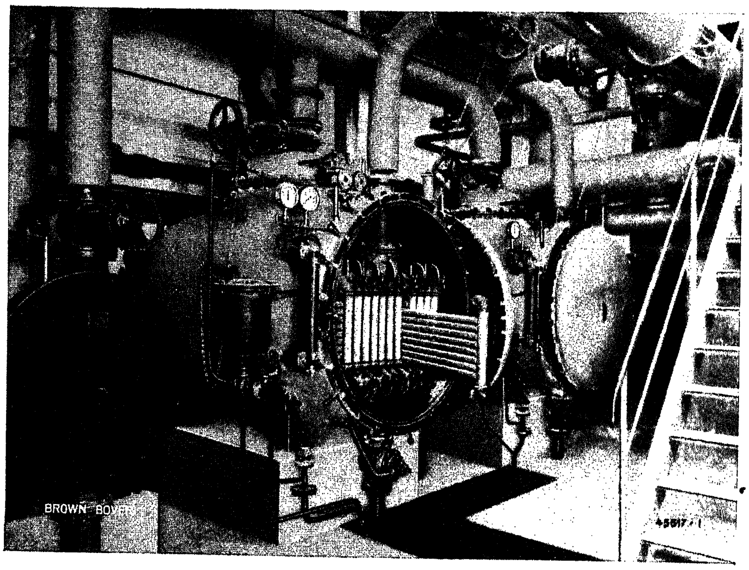


Fig. 19. — View of evaporating and preheating plant.

L = Blow-down quantity in % of feed-water quantity.
S = Total salt concentration of feed water in mg/l.
G = Limit value of salt concentration in boiler water in mg/l.

Of all the chemical processes used, the raw-water treatment on the base-exchange process gives the highest degree of softening but, as regards salt concentration of the feed water, it is, nevertheless, not so good as other processes.

The evaporation process always gives good results in every respect and in the simplest way. The product of distillation from a properly dimensioned evaporator is always free from salt. The residue from evaporation obtained from Brown Boveri evaporators can be proved to contain only about 5 mg/l. This explains why the boilers of certain power stations known to us no longer require to be blown down regularly, after the introduction of the evaporation process to the said stations and this whatever type of boiler they may contain.

In Velox plants, with their short pipe lengths between steam generators and machine sets, the loss of condensate can be kept very low. When, further, the danger of salt getting into the condenser water has been practically eliminated, by putting in condenser tubes which have been subjected to proper thermal treatment and are expanded into the condenser plates, the frequency of boiler blow-down operations is reduced so far that at least a make-up water quantity of 2 to 3 % is certain to be sufficient.

Even in the case of a peak-load and stand-by plant, raw-water treatment by evaporation is economical under these circumstances and is to be given preference over other processes, on account of its practical advantages in service. This is, especially, the case in plants like the one described where the raw water is relatively soft so that a first-stage chemical purification process can be eliminated. The Oslo Electricity Works decided that the evaporation process was the most advantageous and equipped the plant with two evaporators connected in parallel which, together deliver 5000 kg/h at full load. The vapour from the evaporator is condensed in a distillate condenser in which the feed water is heated up to 60—70° C while the hot condensate, itself, is led back to the main condenser and thoroughly deaerated there. The condensate from Brown Boveri condensers has, only, got an oxygen content of 0·05 cm^3/l.

This opportunity is taken to recall the many advantages inherent to Brown Boveri evaporators. They deliver a distillate which is, practically, pure. The raw-water side can be cleaned in a very short time thanks to the design which allows of each, separate, tube coil being dismantled independently, as is seen in Fig. 19. The evaporators have an automatic regulator which renders superfluous special supervision of the apparatus.

PLANT FOR THE SUPPLY AND TREATMENT OF FUEL.

As is seen from Fig. 20, each Velox steam generator has its own fuel-treatment plant. It is composed of the steam-heated preheater of surface type and the fuel-filtering apparatus (Fig. 21). These devices are mounted in close proximity to the Velox they serve and are in duplicate in both cases, in order to allow of cleaning without interruption of service. The preheaters are so dimensioned that thick liquid fuels can also be brought up to the requisite temperature for obtaining satisfactory atomization.

The fuel pump attached to each Velox works to constant pressure at all Velox loads, the magnitude of which pressure is determined by the degree of fine atomization of the fuel, required to get perfect combustion. There are spring-loaded valves behind the pump to maintain the pressure, over which valves the superfluous fuel flows back to the tank.

Account must be taken of the fact that the most advantageous atomatizing temperature varies considerably for the different kinds of fuel oil and that the said temperature must be maintained about constant for a given fuel, independently of the load on the Velox. In order to fulfil this condition, intensive swilling by means of the fuel oil itself of the whole conduit system is one effective measure, among others. This applies especially to the length of pipe between fuel pump and Velox, for which reason, a part of the superfluous fuel is brought close to the fuel nozzle. This allows of attaining perfect and smokeless combustion, at starting as well and also under the lowest loads.

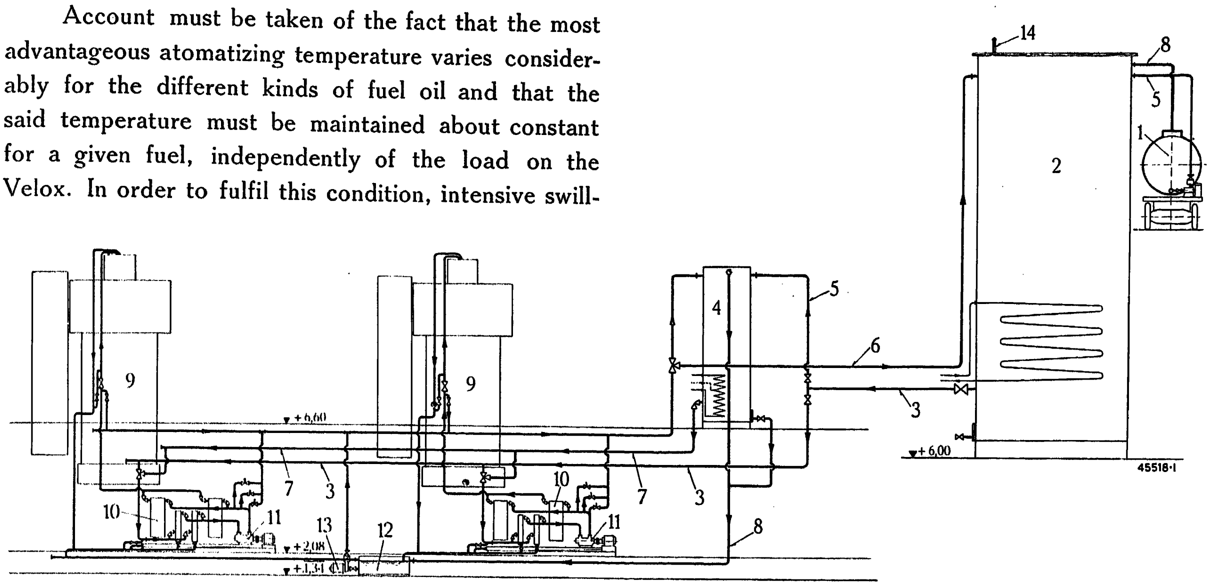


Fig. 20. — **Fundamental diagram of fuel treatment and storage.**

1. Fuel tank car.
2. Main fuel tank.
3. Fuel pipe to Velox and to starting tank.
4. Starting tank.
5. Filling pipe to starting tank.
6. Swilling pipe.
7. Starting pipe.
8. Overflow pipe.
9. Velox.
10. Fuel filter and preheater.
11. Fuel pump.
12. Fuel leakage and evacuation tank.
13. Fuel-leakage pump.
14. Deaeration.

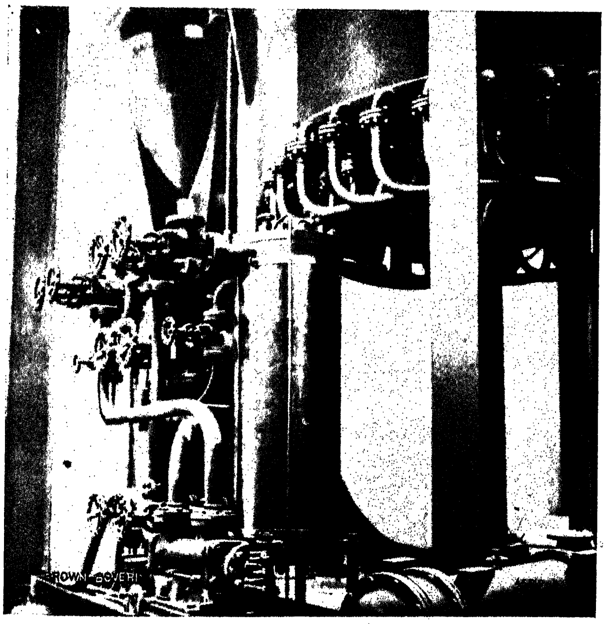


Fig. 21. — **Fuel treatment plant of each Velox.**
Composed of fuel pump set, two preheaters and two filters.

The main fuel tank is in a side room of the same building. The dimensions of the available chamber limit the contents of the tank to a useful capacity of 300 m^3. This tank is equipped with a device to heat up the fuel by means of low-pressure steam, which is always available as it is taken from an electric boiler, when the plant is stopped. In order to impart to heavy fuel oil the necessary viscosity for perfect service, a heating up to about 50^0 C is necessary. Further, the tank is equipped with all necessary fittings, among others, with an apparatus for measuring the filling and with a remote-reading thermometer and electric remote-controlled valve in the fuel-discharging pipe.

The tank is welded out of boiler plating and completely walled in at the request of the municipal building authorities and provided with a reinforced concrete roof.

The considerable distance between main tank and Velox called for special measures to prevent stoppages in the inflow and outflow pipes for fuel. These pipes are laid open, to make them accessible but are placed together with the steam piping and covered in by a common heat-insulating jacket.

In order to allow of quick starting of the plant, independently of the heated-up state of the contents of the main tank, there is a starting tank near the Velox. This second tank has an electric heating device the power input to which can be regulated

between 0 and 40 kW. The desired temperature is maintained by thermostat regulator. Once heated, the power requirements for keeping up the temperature, during pauses in service of the plant, are very low as there are, only, the heat losses by radiation to be made up and these are very low due to the low heated-up temperature required.

In the case of long stoppages, it is recommendable to empty the whole pipe system, in the case

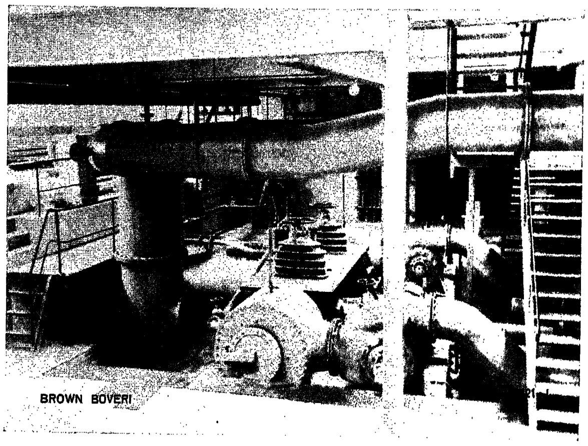


Fig. 23. — View into cooling-water pump room.

of heavy fuel oils. There is a special oil evacuation tank for this purpose and the fuel can be pumped back again out of it to the main tank by means of a small pump.

The instruments and apparatus for measuring, for service supervision and for remote control of the main tank are mounted in a separate panel in the machinery hall.

PIPE LINES.

The pipe lines are no inconsiderable item in the first costs of a thermal power house. Therefore, the present-day attempts towards simple and, consequently economical layouts result in savings in the very expensive high-pressure steam piping. But on purely technical grounds, as well, the planning of all the pipeline installation calls for thorough study and especial care:— the more compact the power plant the greater the importance to be attached to the pipeline layout. A high degree of station reliability demands that the said layout be not only simple in itself but also be easy to supervise and be very accessible.

Cooling-water supply calls for suction and pressure pipes of big dimensions. The layout adopted is seen in Figs. 22 and 23. The elevation shows how these pipes are connected up to the existing inlet and outlet pipe lines which connect the station to the port. Special measures were required to evacuate the suction pipes so as to fill them with water. To this end, there is an electrically-driven pump set which forms a whole with a water ejector. The water of the ejector flows in a closed circuit and is deaerated in a tank inserted on the said circuit.

Usually, the long suction pipe between harbour-water intake and closing-off slide valves in front of the cooling-water pumps will be kept full of water even when the stand-by station is shut down, because there is cooling water wanted for special purposes, such as transformer cooling. The readiness for service of the plant is increased by there being cooling water quickly available.

The live-steam pipes are especially interesting. As Fig. 24 shows, they are very simple and short. The number of fittings and flanges has, also, been reduced to a minimum and the sources of trouble reduced by so much. On the boiler side, there is a safety valve against pipe bursting provided, for each unit, apart from the main steam valve. Only the most resistant type of autogenous-welded H. D. flanges are used. There is no water separator put in. Efficient automatic dewatering, necessary because of condensation phenomena during starting, suffices, on account of the short distances separating boiler and machine

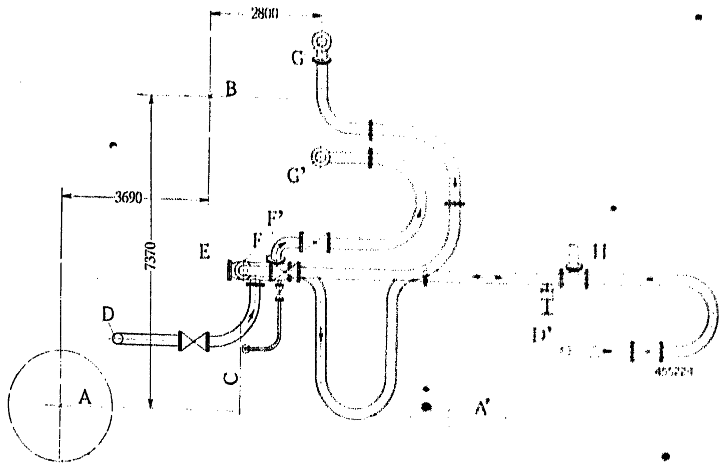


Fig. 24. Layout of live-steam pipe.

A. Middle of Velox No. II.
A'. Middle of Velox No. I.
B. Turbine axis.
C. Middle of turbo-feed pump.
D. Live-steam pipe from Velox II.
D'. Live-steam pipe from Velox I.
E. Steam collector.
F and F'. Live-steam pipe branches to turbo-set on live-steam collector.
G. and G'. Live-steam branch to turbo-set.
H. To throttling post.

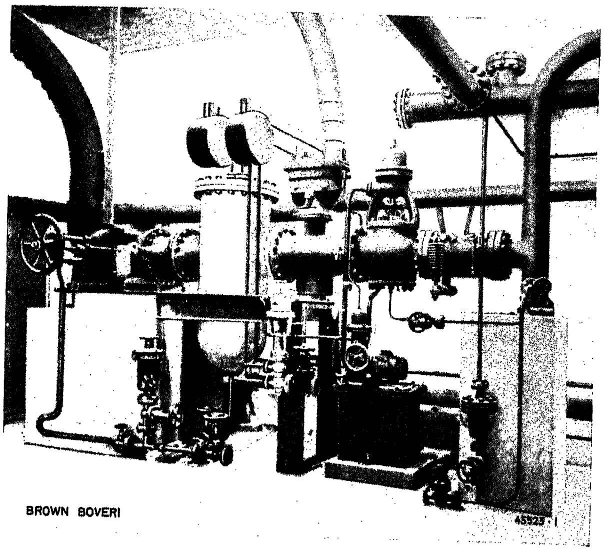


Fig. 25. — Steam-pressure throttling and cooling station.

and the correspondingly small volume represented by these pipes and taking into account the efficacity of the water-steam separator used in the Velox, which has been mentioned before. The dewatering device utilized is placed at the lowest point of the live-steam piping, namely on the steam collector.

Both Velox are connected to a cast-steel steam collector of the smallest dimensions which is designed to form a fixed point, as well. The decision to use a collector was made, chiefly, with the possibility in view of supplying the old portion of the steam stand-by station from the Velox generators, as well, through a throttling station (Fig. 25).

Further, this offers the possibility to couple up boilers (which may be put in for enlargements later) to the existing live-steam system.

Experience shows that peak-load and stand-by turbo-sets are exposed to a certain danger of corrosion, when not operating, this is due to seepage

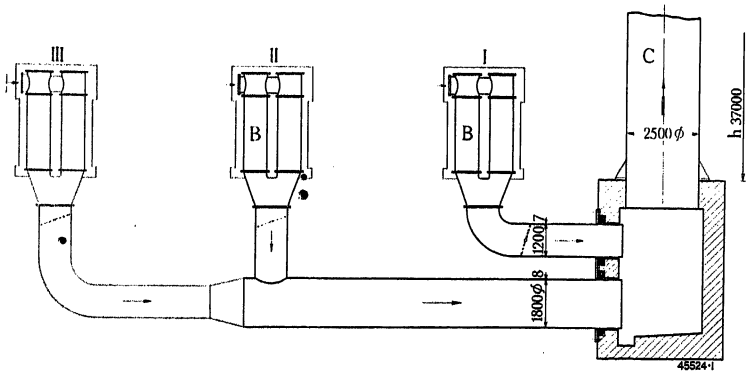


Fig. 26. — Diagrammatic representation and layout of combustion-gas channels.

I. Velox steam generator I.
II. Velox steam generator II.
III. Velox steam generator III (for future extensions).
B. Preheater.
C. Exhaust-gas duct.
h. Total height of stack.

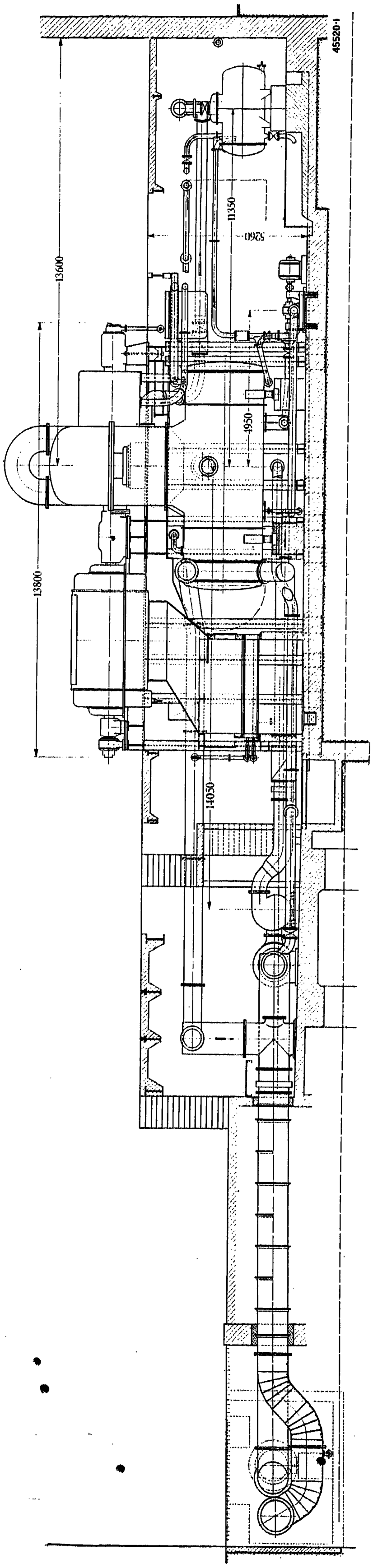


Fig. 22. — Arrangement of the cooling-water pipes.

steam. It is best prevented by aeration of the live-steam pipe. To this end, special aerating valves have been inserted between boilers and machines.

The steam which may be blown off by the safety valve of the boiler is led straight to the chimney by exhaust-gas pipes.

The big amounts of combustion air required for the Velox are taken from the free atmosphere above the roof and are led through walled-in ducts inside the boiler chamber side-walls to below the floor of the machinery hall, from here the air is carried to the compressors of the Velox by iron piping.

The exhaust-gas channels are worthy of note on account of the big quantities of gas which must be handled. Steam generators of this size are generally connected to the smoke stack through walled-in ducts. In the case of the Velox the pressure reserve available allows of imparting considerable velocities to the gases in the gas ducts, so that it was found possible to use forged iron pipes of relatively moderate dimensions. These gas channels are located under the floor of the main-service gangway, as seen in Fig. 26. This arrangement takes into account the requirements of a future enlargement of the steam generating plant. The manner in which the connection to the stack is made allows of free expansion of these long pipe lines. The stack, itself, is formed of sheet-metal sections bolted together and it is only 37 m high; it is carried on a reinforced-concrete base.

There is a special coating of protective paint on the outside and inside of the cooling-water pipes, the exhaust-gas pipes and the stack. All steam and hot-water pipe lengths as well as containers and the exhaust-gas pipes are carefully insulated against heat losses.

CRANE EQUIPMENT OF THE MACHINERY HALL AND STEAM-GENERATING PLANT.

The plant is equipped with the following travelling cranes:—

1. For erection and overhauling of the turbo-set:— one travelling crane for a total useful load of 45 t with electric drive for hoisting, longitudinal and transversal travel.
2. For erection and overhauling in the steam-generating plant:— one travelling crane for a total useful load of 25 t with electric drive for hoisting, longitudinal and transversal travel.

All motors of these cranes are connected to a low-voltage supply system, 230 V.

There is no especial need of a travelling crane in the Velox plant. For erection, the usual hoisting gear could have been made to suffice while a pulley block of relatively small hoisting capacity would have sufficed for the overhauls to be carried out. It should be said, however, that the installation of a travelling crane dimensioned for the heaviest pieces to be hoisted during erection proved well worth the outlay for it. Without it, it would not have been possible to have got the plant ready for service in the short time specified. The availability of a travelling crane in the steam-generating plant naturally facilitates overhauls and its use did not entail increasing the height of the building because of the little head room taken up by the Velox steam generators themselves. The outlay for putting in the cranes is very slight as compared to that of the whole plant and seems indicated from the practical point of view.

THE ELECTRIC SWITCHING, REGULATING AND PROTECTIVE DEVICES FOR TURBO-GENERATOR AND MAIN TRANSFORMER.

Fig. 27 shows the main connections of the electrical side of the steam power station. Electric-power distribution in the town of Oslo is through a high-voltage system at 30,000 V and a medium-voltage system at 5000 V.

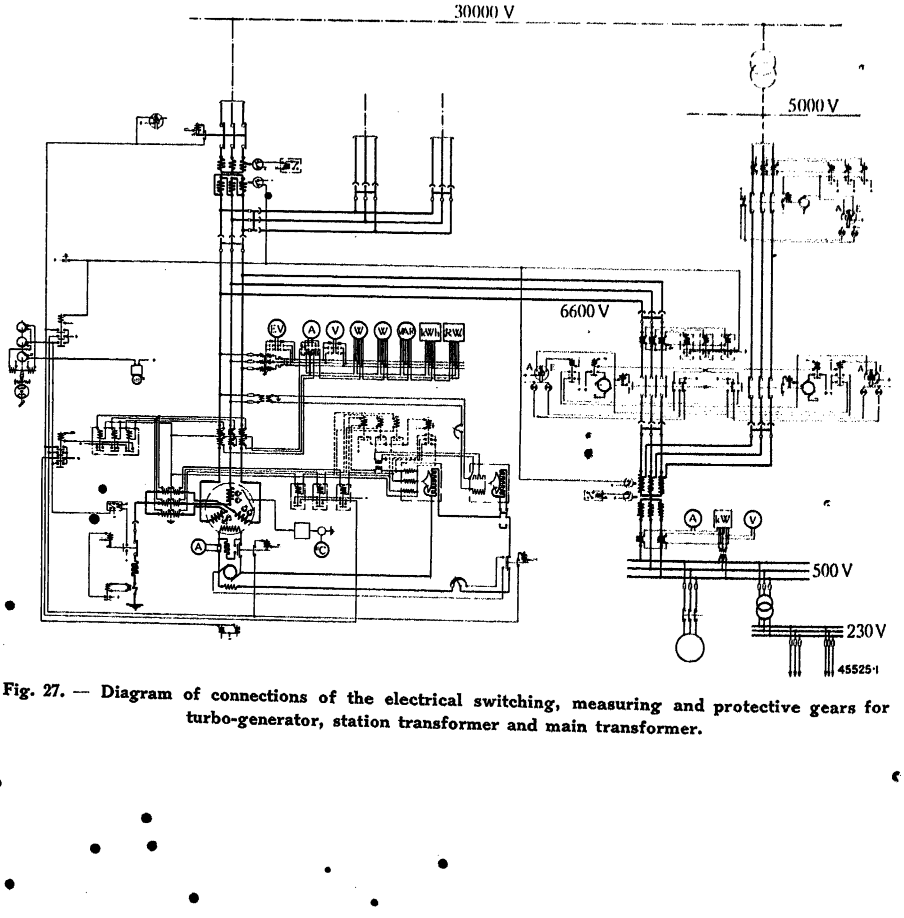


Fig. 27. — Diagram of connections of the electrical switching, measuring and protective gears for turbo-generator, station transformer and main transformer.

The new turbo-generator works through a step-up transformer of the same output, built for 6600/30,000 V, on the bus-bars of the high-voltage system. The machine is, solely, switched in on the 30-kV side for which an oil circuit breaker, dimensioned for the characteristics of the machine and system, is utilized.

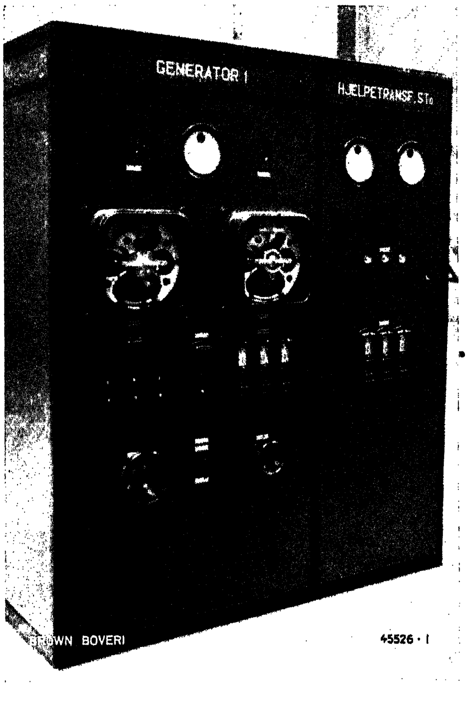


Fig. 28. Regulator and relay panel of the turbo-generator.

The turbo-generator is equipped with all the requisite regulating and protective devices. An automatic quick-acting voltage regulator keeps the terminal voltage constant. When short circuits or over-loads occur, outside the generator, an over-current limiting regulator acts as a protection and brings down the excitation of the generator accordingly. There is also the possibility of providing this regulator with a blocking device so as to allow it to act only after two or three seconds have elapsed. In all cases in which the selective protection of the power distributing plant will allow of the fault being cut out within the said lapse of time, the over-current limiting regulator on the generator will not be called on to intervene. This selective protection is not put in yet, however.

In the case of short circuits inside the generator, itself, there is a three-pole differential relay which acts to trip the main circuit breaker and demagnetize the generator, at once, further it actuates an equipment to suppress fires. As the generator only works on transformers, a simple earthing device in the form of an earthing resistance could be used, which reduces the earth current to about 10 A if an earthing on one phase occurs. A current transformer on the earth conductor supplies an over-current relay which signals the occurrence of an earth and opens the breaker of the earthing connection of the neutral point.

The main transformer is equipped with Buchholz protection.

Finally, as regards the measurement devices and those necessary for operation and supervision, reference is made to Fig. 27. Apart from the usual instruments, there is a device for measuring the temperature of the generator at six different points on the machine.

The measurement instruments as well as those for operation and supervision are lodged in a switchboard desk mounted in the supervising chamber. All relays for generator protection as well as the automatic voltage and over-current automatic regulators are on an instrument panel beside the turbo-generator, itself. This panel also carries the operating instruments and the apparatus for serving the station transformer.

A machine telegraph equipment facilitates rapid communication between the operators in the control room and those in the machinery hall.

To complete the description, it should be added that the main transformer can be utilized when the

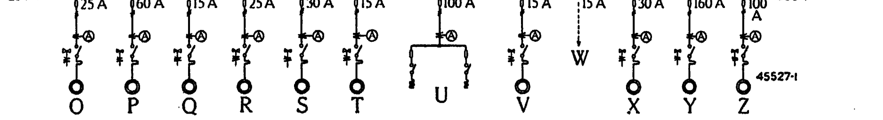


Fig. 29. — One-pole diagram of connections of the auxiliary services.

B. Cooling-water pump sets.
C. Ejector and condensate pump sets.
D. Feed-water pump set.
E. Circulating-pump set (Velox 1).
F. Fuel-pump set (Velox 1).
G. Circulating-pump set (Velox 2).
H. Fuel-pump set (Velox 2).
J. Auxiliary transformer 500/60 V (for Velox steam generator).
K. Auxiliary transformer 500/60 V (for Velox steam generator).
L. Ward-Leonard converter set.
M. Ward-Leonard converter set.
N. Transformer 100 kVA, 500/230 V.
O. Motor to turn over turbine shaft.
P. Ejector suction-pump set.
Q. Pump-set for dirty water.
R. Oil-pump set of main transformer.
S. Cooling-water pump set of main transformer.
T. Leakage fuel-pump set.
U. Heating device of starting tank.
V. Oil-pump set of steam throttling post.
W. Oil-pump set of steam throttling post.
X. Condensate leakage pump set.
Y. To crane 45 t (machinery hall).
Z. To crane 25 t (boiler room).

TABLE I.

List of all the auxiliary machines installed in the plant.

	Coupling-rated output of driving motors kW	Speed r.p.m.	Terminal voltage V	Kind of current
1. *Auxiliaries for the two Velox steam generators:—*				
2 fuel-pump sets each	15	1450	500	3-phase
2 pump sets incl. the boiler circulation pump and lubricating oil and governing oil pump, each	125	1460	500	3-phase
2 charging sets with starting and regulating motor each	320	1180	440	direct current
2 complete Ward-Leonard sets including each:—				
1 three-phase motor	400	985	500	3-phase
1 D.C. generator	340	985	440	d. c.
1 exciter	5	985	115	d. c.
1 electric-driven feed-water pump set	280	2950	500	3-phase
1 steam-driven feed-water pump set (as a stand-by)	280	3400	—	—
2. *Auxiliaries for the turbo-set:—*				
2 cooling-water pump sets with electric-motor drive, each	140	975	500	3-phase
2 condensate jet-ejector pump sets with electric motor drive (1 as stand-by), each	95	1450	500	3-phase
1 shaft rotating device with electric motor	3·3	960	230	3-phase
1 water ejector-air pump set to deaerate the cooling water system, with electric motor	11	2900	230	3-phase
1 condensate-auxiliary pump set for leaks, with electric motor	4·5	2850	230	3-phase
3. *Auxiliaries for the main transformer:—*				
1 oil-circulation pump set with electric motor	2	1420	230	3-phase
1 cooling-water pump set with electric motor	4·5	1420	230	3-phase
4. *Crane for turbo-set and Velox steam generator:—*				
1 travelling crane electrically driven by 3 motors, for a max. hoisting load of 45 t, in the central bay	33·5·9	—	230	3-phase
1 travelling crane with electric drive by 3 motors, for a max. hoisting load of 25 t, in southern bay	13·3·6	—	230	3-phase
5. *Other auxiliaries:—*				
1 fuel leak oil pump set with electric motor	0·37	1380	230	3-phase
1 oil-pressure governing set for steam-throttling station with electric motor	1	2900	230	3-phase
1 dirty water pump set with electric motor	1·0	1390	230	3-phase

steam generating plant is not running, for the supply of an electric boiler, which is also in the new building.

SUPPLYING THE REQUIREMENTS OF THE STATION FOR THE DRIVE OF AUXILIARIES.

The kind of drive best suited to the auxiliaries is evident, at once, in the present case. Taking into account the character of the plant and the advantageous conditions existing as regards the obtainment of power from an external system, it was obvious that the use of electric drives throughout was advisable. The only exception is the case of the two boiler feed pumps for which another source of power had to be found, in order to meet the regulations in force in the country.

For the same reasons, there was no need to put in a separate station set. The whole power requirements for the drive of the auxiliaries comes from a station transformer of 1600 kVA, 6600/5000/500 V. It has six terminals on the primary side and can be supplied either from the medium-voltage system at 5000 V or else direct from the generator terminals at 6600 V. The breakers between generator terminals and station transformer on the one hand, and between the 5000-V system and the station transformer, on the other, are so mutually interlocked that only one of the two can be closed at one time. This transformer, as well, has the Buchholz protection.

The motors of the auxiliary drives of the plant are supplied with low-voltage, i. e. maximum 500 V and protected by fuses, thermal relays and low-voltage tripping devices. All the big motors are connected straight to a 500-V bus-bar.

There is another transformer, of 100 kVA, 500/230 V output. It gives the power required for the small motors.

Finally, mention must be made of two further small auxiliary transformers 500/60 V for the supply of the protective and signalling apparatus of the Velox plant.

In Fig. 29 the fundamental diagram of connections for power distribution for the auxiliaries is shown, in one-pole arrangement.

The distribution bus-bars at 500 and 230 V are lodged with the fuses of the supply lines in a switchboard having several panels, which is in the underground chamber of the station. Switches and relays of all the motors are lodged in switchboxes, part of which are equipped for remote control.

Finally, attention should be drawn to the advantages of the switching-over possibilities on the

TABLE II.

Steam-, heat- and fuel-consumption figures of the Velox plant.

Load delivered at generator terminals in kW at p. f. = 0·9		31,500	21,000	15,750	10,000
Live-steam pressure and temperature at Velox delivery branch		28 kg/cm² and 425° C			
Heat content of live steam at Velox delivery branch	kcal/kg	787	787	787	787
Temperature of Velox feed water	°C	70	60	56	52
Total heat utilized per kg of steam in the Velox	kcal/kg	717	727	731	735
Velox steam generator efficiency	°C	92·4	91·8	92·4	91·8
		2 boilers in service		1 boiler in service	
Live-steam pressure and temperature at the turbine inlet		27 kg/cm² and 420° C			
Absolute pressure in condenser at 5° C at cooling water inlet	kg/cm²	0·043	0·029	0·024	0·020
Steam consumption at 5° C cooling water temperature and with preheating of feed water according to above data, referred to generator output at terminals	kg/kWh	4·22	4·02	4·02	4·14
Heat consumption without boiler losses and referred to generator output at terminals	kcal/kWh	3025	2922	2938	3042
Heat consumption including boiler losses according to above efficiency data and referred to generator output at terminals	kcal/kWh	3275	3180	3180	3320
Total power required for all the auxiliaries drawn from the three-phase system	kW	880	765	550	455
Additional losses in auxiliary transformer	kW	40	35	30	25
Total amount of power for auxiliary drive including transformer losses	kW	920	800	675	615
Ditto in % of generator output at terminals	%	2·9	3·8	4·3	6·1
After deduction of losses for auxiliary drives the effective output is	kW	30,580	20,200	15,075	9385
Total heat consumption referred to useful effective output	kcal/kWh	3370	3301	3320	3540
Fuel consumption referred to effective useful output, not including losses in main transformer when a fuel is used having Hu = 10,000 kcal/kg	kg/kWh	0·337	0·330	0·332	0·354
The power requirement (referred to 3-phase system) for the auxiliary services is divided up as follows:—					
Fuel-pump sets	kW	16	—	8	—
Circulation-pump sets	kW	170	—	85	—
Charging sets are fed from the Ward-Leonard converter sets and drawn no power straight from the 3-phase system	kW	—	—	—	—
Ward-Leonard converter sets	kW	180	—	90	—
Electric driven feed-water pump sets	kW	220	—	200	—
Steam-turbine driven feed-water pump set (as stand-by)	kW	—	—	—	—
Cooling-water pump sets	kW	220	—	220	—
Condensate, ejector water pump sets	kW	70	—	70	—
Various small motors	kW	4	—	2	—
		880		675	

primary side of the station transformer. For starting up, power is drawn from the 5000-V system and, during running, direct from the generator terminals. This gives a great degree of reliability for the auxiliary services as the supply of power to the said auxiliaries is made independent, in this way, of possible disturbances in the system.

EFFICIENCY.

The calorific and consumption figures attained in this plant for the whole interesting range of output correspond to an overall thermal efficiency of 25 %. This result can be considered as excellent for a steam plant of this kind. The same results were confirmed by thorough tests carried out, before the taking over of the station, by the Oslo Electricity Works and which were carried out by Prof. Dr. A. Watzinger of Trondheim.

The power consumption to run the auxiliaries is 2·9 % at full load and 4·3 % at half load and is, thus, below the range of values published for other power stations.

Hellmich publishes the corresponding figures of coal-fired big power stations in America and designates an average for station purposes of eight steam power stations of about 5 % of the power delivered [1]. Attention should be drawn, when on this subject, to the low consumption of electric power for the charging sets of the Velox steam generators. As the table given shows, the Ward-Leonard set and the auxiliary motor are only weakly loaded under steady delivery conditions. They are always amply dimensioned to take account of quick-starting requirements and to obtain a big range of regulation. The extra power drawn from the electric system for the charging of the Velox and, therefore, indirectly, for the generation of the high gas velocities, amounts, after inclusion of all conversion losses, to a fraction of one percent for the interesting range of Velox loading.

In certain cases, electric power may even be delivered back to the supply system. We would refer here to the results of tests carried out on a 45-t Velox steam generator on the test bed which were published in the Jan./Febr. 1937 number of The Brown Boveri Review, page 11.

In spite of the high velocity of the combustion gases, the power input to the Velox auxiliaries is low. The position of the Velox steam generator, in this respect, is quite singular, and this is a point worth stressing. As is known, the whole field of steam generation development is marked, to-day, by efforts to utilize the advantages inherent to high velocities of the combustion gases. The possibilities of so doing, however, are restricted, because these high velocities mean the expenditure of big quantities of power which, of course, affects the economical qualities of the boiler disadvantageously, unless the said power can be obtained at no cost from a turbine run by exhaust gas and not obtained from the electric supply system.

READINESS FOR SERVICE.

The present station made no extreme demands on the generating plant, as regards readiness for service, because the power station works, chiefly, as a peak-load plant, as was said at the beginning. It is, therefore, all the more remarkable that the new plant can take over load within about 30 minutes, without any special measures being taken or overstressing of the material. Starting from the cold state, the Velox steam generators can be put under pressure, within a few minutes, only and, if required, the turbo-set can be brought up to full speed in about 20 minutes, so that it is ready to be paralleled with the system and put under load.

Mention was made in the Jan. Febr. number, 1937, of The Brown Boveri Review that the work for preparing the area available for the new plant was only begun at the beginning of 1936 and that, as early as November of that year, the starting-up of the station could be begun with. After the putting to work, the three-months probationary run, required by contract, was begun and, when this was accomplished, the Oslo Electricity Works took over the station. It should be said, here, that a third Velox steam generator of the same size has now been ordered for the Oslo plant from Brown Boveri.

The Electricity Works of Oslo have rendered a service to technical progress in the field of power generation by the setting up of this new plant, as this is the first station utilizing Velox units of this size. The Oslo Electricity Works did not take this decision without due consideration or with blind confidence in the manufacturer. Their specialists investigated all the eventualities and possible risks and only came to a definite decision after getting convincing running reports from other, although smaller, Velox plants; they then entrusted the building of the whole equipment to Brown Boveri. This plant is not only an interesting one on account of the Velox units it contains, but also owing to the unity and logical execution in accordance with the guiding principles which should govern the layout of a peak-load station. Inspection of this plant can be warmly recommended to all power-station engineers having to plan new plants or modernize existing ones.

To conclude, it may be said that the building of the plant meant the placing of important orders for material with Norwegian firms. Further, all building alterations were in the hands of Norwegian contractors while the major part of the erecting staff was drawn from the town of Oslo.

The successful results both as regards planning and execution of the work is due, in no small degree, to the thorough and valuable technical collaboration of the Electricity Works of the Town of Oslo.

(MS 555)

A. Fischer. (Mo.)

[1] Elektrizitätswirtschaft; No. 2, 15th Jan., 1937:— "Die Deckung des Eigenbedarfs der Kraftwerke insbesondere in den Vereinigten Staaten von Nordamerika", by Dr. H. Hellmich VDI.

SOME COMMENTS ON THE TRANSVERSAL DIFFERENTIAL PROTECTION OF DOUBLE LINES, ON SYSTEMS WITH EARTHED NEUTRAL.

Decimal index 621.316.925.4.

I. INTRODUCTION.

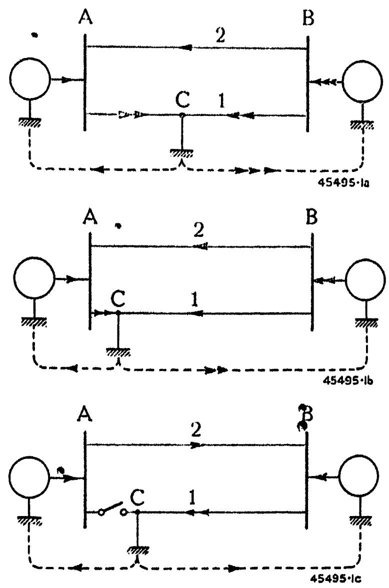
WHEN a system is composed of double lines terminating at both ends in common bus-bars, the protection of these lines by differential relays suggests itself, naturally. In any double line which has no fault, the currents flowing in the two three-phase lines will always be equal, phase per phase, but this ceases to be the case if one of the two lines develops a defect.

The differential protection described in the following paragraphs can be utilized in the particular case of networks the neutral point of which is straight earthed. As compared to ordinary systems of differential protection, it presents several advantages which tend to eliminate the objections usually raised to the differential protection of lines. The application of this new system allows of attaining an ultra-rapid selective protection, in a very simple manner.

II. PRINCIPLE AND DESCRIPTION OF DIFFERENTIAL PROTECTION BY TOTALIZED CURRENTS FOR SYSTEMS WITH STRAIGHT-EARTHED NEUTRAL.

In order to prevent all confusion, we state here, that the system of protection described in the following paragraphs includes all single- or two-pole short circuits to earth occurring on double lines. This protection does not act for cases of short circuits insulated from earth or of three-pole short circuits to earth affecting, from their initiation and symmetrically, all the three phases; these cases are relatively rare.

The principle of protection is the following one. Consider Fig. 1. Assume an earth fault at C on line 1. The fault current flows from C towards A and towards B, the actual strength of these partial currents depending on the zero sequence impedances of the elements making up the system. It is easy to understand that the fault current will always be stronger in the damaged line than in the sound one; this is obvious in the case of Fig. 1. In the case of Fig. 2, the fault occurs on line 1, close to A, right at the end of the line. The fault currents at B in lines 1 and 2 are, obviously, equal, while at A, the fault current in line 1 is greater than in 2, because of the addition of the fault current coming from B.



Figs. 1, 2 and 3. — Examples of partition of fault current flowing through the ground.

A, B. Stations.
C. Short circuit to earth.
1, 2. Lines.

In order that the defective line should carry a fault current bigger than the sound line, it is necessary and sufficient that the neutral point of the system be earthed on both sides of the section being protected. It is unnecessary that these earthings be carried out in the stations A and B, themselves, they can be made at any point further away than A and B.

Thus, in order to eliminate the defective main line automatically, it will suffice to compare the absolute values of the fault currents of the two lines and to cut out the one which is the seat of the strongest current. In the case of Fig. 1, the cutting out will be instantaneous at both ends. In the case of Fig. 2, on the contrary, the cutting out will only be instantaneous at point A. Immediately after this cutting out, the relay at B will act and cut out the other end of the defective line (Fig. 3).

The diagram of Fig. 4 shows how this system of protection is carried out, in practice. To measure the fault current in a line, it is sufficient to form the sum of the currents in the three phases. The fault current is equal to the current circulating through

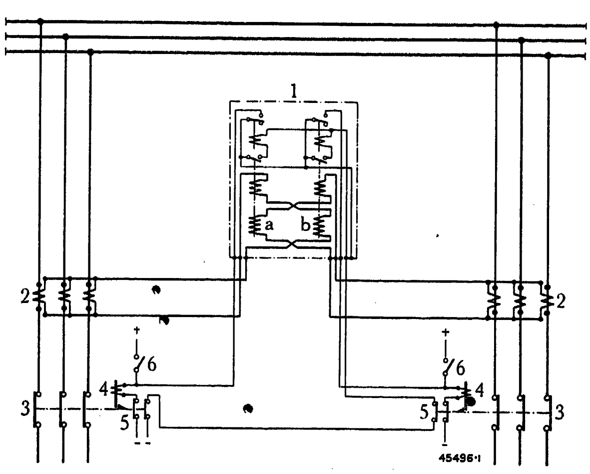


Fig. 4. — Fundamental diagram of connections for differential protection against earth faults on a double line.

the common return lead of the three current transformers. Under ordinary service conditions this current is zero and it only appears when a fault to earth occurs on the system. The two differential relays 1a and 1b compare the fault currents in the two lines. Relay 1a is on the left line and relay 1b on the right one. The fault current of the left line flows through the lower coil of relay 1b (holding coil) and then through the upper coil of relay 1a (tripping coil). In the same way, the fault current of the right line flows through the holding coil of relay 1a and the tripping coil of relay 1b. There are a few more turns on the holding coils than on the tripping coils. When the fault current of the left line is some percentage bigger than that of the right line, the tripping coil of relay 1a is more strongly excited than its holding coil. This relay acts and causes breaker 3 to trip; relay 1b acts in similar manner for the right line.

A recall spring maintains relays 1a and 1b in the open position when the fault current is zero. An essential characteristic of the device is that, when the fault currents of both lines are equal, no relay is excited. In order to make a relay act, not only must the current through the tripping coil be strong enough to overcome the recall spring but it must also exceed by a certain percentage the current through the holding coil. Thus, the relay is independent of unavoidable errors in the current transformers. This is a compensated differential relay which, as compared to the ordinary differential relay, has the advantage of great sensitiveness as regards low fault currents and, by adjustment, of complete insensitiveness as regards errors of the current transformers, even in the case of violent short circuits beyond the protected line section.

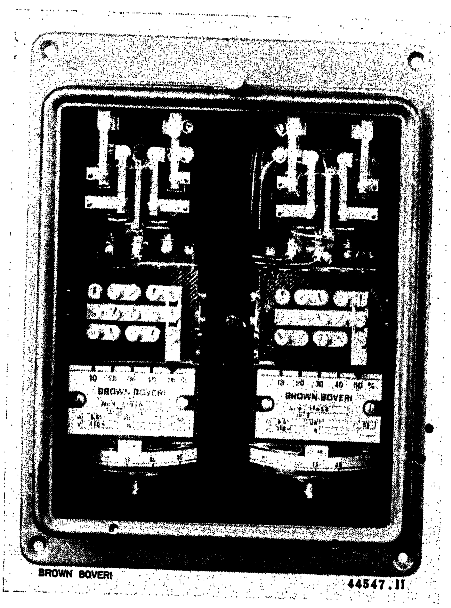


Fig. 5. — **Percentage differential relay.**

The photo in Fig. 5 shows the compensated differential relay. The two coils are arranged one above the other; the tripping coil is located below, behind the indicating plate, the holding coil is placed above and carries the taps allowing of adjusting the number of turns. The lower scale allows of setting the recall spring. Above the relay and in the same casing there is a small auxiliary contactor controlled by the contact of the differential relay, the latter being, usually, too weak to perform the straight closing of the tripping circuit of a breaker.

The relay consumes about 4·5 VA per coil under ordinary calibration. Thus, the load introduced into the neutral lead of the three current transformers, when a fault occurs, is only 9 VA. It is generally possible to use bushing type current transformers. Fig. 6 shows the sensitiveness of the relay.

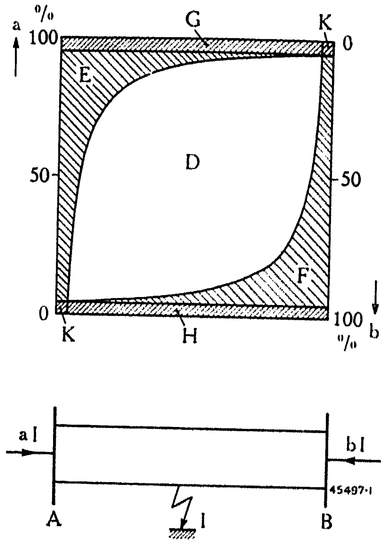


Fig. 6. — **Characteristic of the differential relay.**

Abscissae: Lengths of line (distances).
Ordinates: Portions of the fault current I flowing towards A and B.
A, B. Stations.
I. Fault current.
a, b. Portions of fault current flowing in from A and B.
Surface D. Simultaneous line cut out at A and B.
Surface E. Successive line cut out first at A then at B.
Surface G. Instantaneous cut out at A only, no cut out at B.
Surface H. Instantaneous cut out at B, no cut out at A.
Surface K. No cut out of the line at either end.

Let it be assumed that the fault current I is equal to the rated current of the current transformers placed at points A and B. The fraction a% of the fault current comes from the system on the left of A and the fraction b% from the system on the right of B; a + b being equal to 100%. The distances are indicated in abscissae and the fractions a% and b% in ordinates.

In the D area the two line breakers are tripped simultaneously.

In the E area, the A breaker is tripped instantaneously and the B breaker after A has tripped.

In the F area, the B breaker trips instantaneously while the A breaker trips after B has done so.

In the G area, the fault current from B is too weak to allow of the B relay detecting a difference in the line currents 1 and 2 and only the A breaker trips.

In the H area, the fault current from A is, similarly, too weak to allow of the A relay detecting a difference in the two line currents and only the B breaker trips.

In the two K areas, no tripping takes place.

This diagram is drawn on the assumption that the number of turns on the holding coils is equal to that on the tripping coils. If, now, m % more turns are wound on the holding coil, the curves limiting the D area must be displaced by $\frac{m}{2}$% to the right and to the left, thus reducing area D, slightly.

Under usual conditions, the fractions a and b will always be within the 20 and 80% range so that areas G, H and K need not be taken into account.

If the fault current is bigger than the rated current of the current transformers, area D increases; if it is smaller, area D decreases.

III. SPECIAL CHARACTERISTICS OF DIFFERENTIAL PROTECTION BY TOTALIZED CURRENT.

We give, here, some special features of this system of protection and point out, in particular, its advantages as compared to the ordinary differential protection by phase currents.

When one of the mains of a double line is put out of service, the differential protection must obviously be locked. A differential protection by phase currents has to be locked before any breaker operation is carried out, because, if this is not done, the differential relay will act as under a short circuit on main 2 and will cut out this main at B, whenever the breaker of main 1 at A (Fig. 1) is opened. The differential relay acting on the totalized current system not having any current flowing through it as long as no fault develops on the system, it is possible to cut out a main at one of its extremities without this causing the differential relay at the other extremity to act. Of course, the differential protection must be cut out as soon as possible so that, if a fault develops on the system, the main which is still working is not cut out suddenly. This cutting out of the differential protection takes place automatically, if care is taken to cut out the line being taken out of service, at both ends. An auxiliary differential relay can also be used to produce the cut out, this apparatus comparing the phase currents and cutting out the differential protection working on totalized currents in a few seconds, when the phase currents differ. No wattmetric relays are required for differential protection acting on totalized currents. Directional effect is attained by the comparison of the currents, solely, thus voltage transformers are not necessary.

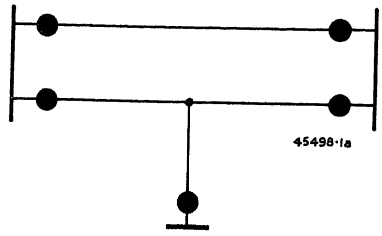


Fig. 7. — Double main line with single branch line.

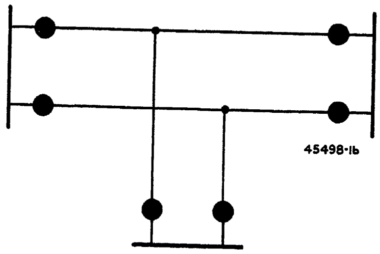


Fig. 8. — Double main line with double branch line.

As compared to protective systems known as Merz Price systems which compare currents at the beginning and at the end of the line, the differential protection acting on totalized currents requires no pilot wire or high-frequency transmission system. It can be used on double lines, even if they have dissymmetrical branches as shown in Fig. 7.

The only necessary condition is that the branch should not contain any transformer, the neutral point

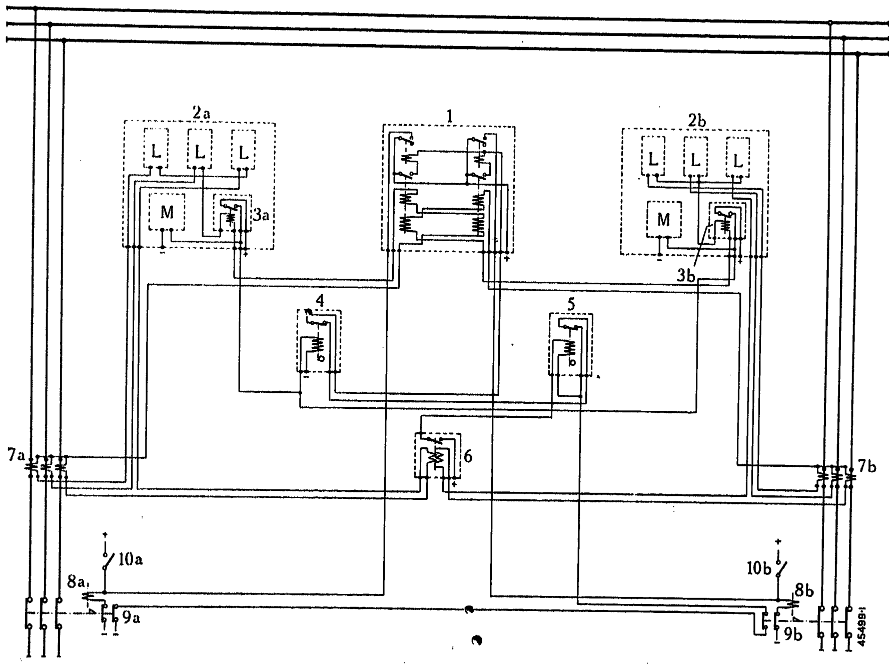


Fig. 9. — Fundamental diagram of connections of differential protection of a double line with interlocking in the case of failure of the current in one line and stand-by protection by distance relays.

1. Differential relay.
2a, 2b. Distance-relay protection panel.
L. Distance relay.
M. Earthing relay.
3a, b. Totalizing current relay.
4. Blocking time-lag relay.
5. Time-lag relay.
6. Current-difference relay.
7a, b. Current transformers.
8a, b. Tripping coils.
9a, b. Blocking contact.
10a, b. Tripping contacts of distance relay.

of which is earthed. This diagram is incompatible with differential protection by phase currents. In the latter case, the lines have to be connected in the way shown in Fig. 8, which is a much more costly matter. Of course, differential protection by totalized currents can also be used in the case of Fig. 8.

Differential protection by totalized currents is efficacious in the majority of cases of disturbance on the network. On the other hand, it is inefficacious in the following cases: symmetrical, three-pole short circuits, short circuits between phases without earth contact, short circuits on station bus-bars; short circuits on lines being utilized, temporarily, as single lines. In these cases of trouble, a spare system of protection should, usually, be provided, either working with over-current relays, or distance relays or any other efficacious system. This stand-by protection acting only as such can be made as simple as possible.

As an example, Fig. 9 shows the protection of a double outgoing line by means of a differential relay on the totalized current system 1, with, as a stand-by, a protection by distance relays 2a, 2b. The cutting out of the differential protection, when operating as single line, is carried out automatically by an auxiliary differential relay 6, combined with the time-lag relay 5. The time-lag relay 4, adjusted to 0·6 seconds, puts the differential relay out of service at the end of that period, automatically. If, after 0·6 seconds after the disturbance, the fault has not been cleared by the differential relay, this is a certain indication that the said relay should not intervene, at all, and that it should be interlocked.

(MS 560) *J. Schneider. (Mo.)*

NEW HIGH-VOLTAGE, HIGH-CAPACITY FUSES.

Decimal index 621.316.923.1.0273.

SINCE about a decade and a half, power systems and plants operating in the higher-voltage ranges were protected by power circuit breakers, exclusively, because it was impossible to attain either the desired selectivity or the requisite rupturing capacity with the fuses then available. Reasons of economy, however, led to investigations being made to find out if, in determined cases, it would not be practically possible to attain protection against short circuits by means of fuses, for example in plants where it is not vitally necessary that the protection be of closely selective character, where service conditions do not make it necessary to rupture under load and where there is no remote control used. The necessary presumption is, of course, that the fuses used are able to rupture considerable loads quite safely and that setting to work again after the fuse has melted is not a long and costly affair. Further, the cost of the said fuse must be low as compared to that of the breaker of the same rupturing capacity.

Brown Boveri concurred with this aim as expressed by certain circles among their clients and, in order to meet the requirements of the said clients satisfactorily, they developed and succeeded in bringing out a new type of high-voltage high-capacity fuse, which meets all modern requirements.

Their high-power testing plant allowed Brown Boveri to make an exact study of the fuse problem. To begin with, attempts were made to increase the rupturing capacity of fuses of the tubular type which had been found insufficient. However, the principle involved was shown to have little scope for development. When the tubes were of big section, the currents ruptured, which were not much above the service values, did not generate a sufficiently strong extinguishing blast to extinguish the arc set up. If, now, the tubes are designed of small section, big current ruptures may cause them to explode because, for constructive reasons, the said tubes cannot be made strong enough to stand up to, relatively, high pressures. Further, as the power ruptured is increased, the incandescent gases expelled and the vapour sheaf formed by the arc itself become increasingly evident and are the cause of flash-overs in the plant when the adjacent parts of the latter are not shielded by special protective devices.

In order to find some better constructive principle for the fuses, various types were subjected to thorough investigation. Oil fuses rupturing very high currents are the seat of extremely high pressures and are liable to explode, thus causing fires. With other known types of fuses with a liquid filling, the danger of fire, but not the possibility of an explosion, is eliminated. Apart from this, the type of fuse working with a tetra-chloride filling generates poisonous gases, when the fuse acts, which attack the surrounding equipment, chemically.

The Brown Boveri tests show that fuses with a sand filling are, also, subject to explosions if not very carefully dimensioned and designed. The investigations carried out went to show, however, that a fuse of very excellent characteristics is obtained, as soon as the section and surface of the fuse wire are properly determined and when the individual strands of wire making up the whole are suitably arranged. Further, the extinguishing powder must possess a big adsorption surface and not form chemical combinations with the melted wire. If these

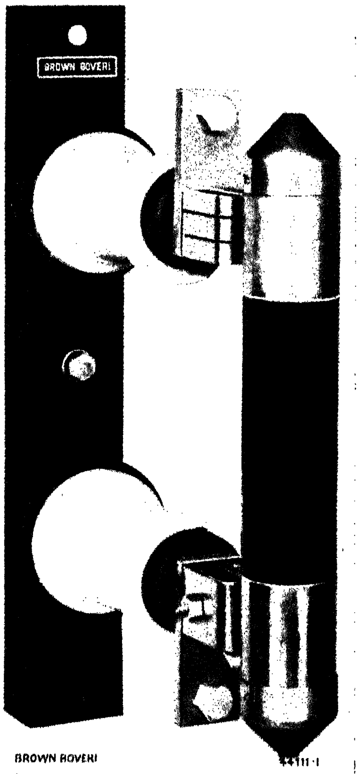


Fig. 1. — High-voltage, high-capacity fuse, for 11 kV, 64 A.

factors are taken into due account, the building up of an internal pressure is prevented, so that there are no external manifestations when the current is ruptured by the fuse. The vapours generated when the fuse-wires melt are diffused in the extinction powder and condense, which causes the current to be cut off through a deionization of its track.

The new fuse is shown in Fig. 1. There are no external manifestations to be detected when the fuse wires melt even when the short-circuit power ruptured is very big. An indicating button is pressed outwards from the lower end cap by a powerful spring, when the fuse blows, so that a blown fuse is recognized, at once.

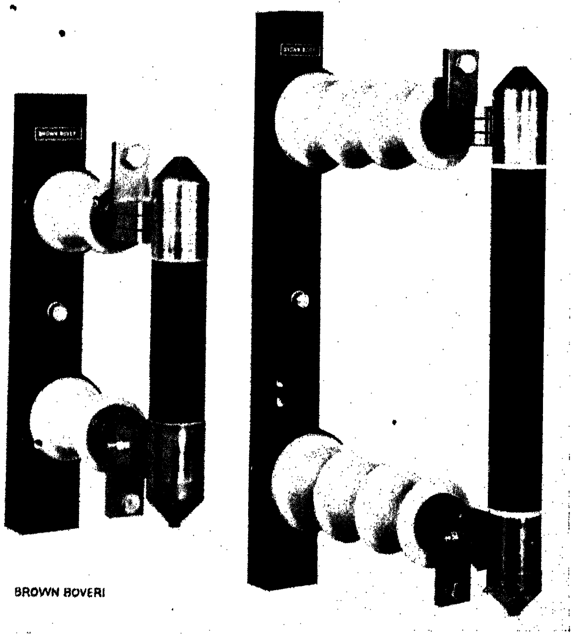


Fig. 2. — Fuses for 6·4 kV, 40 A and for 37 kV, 10 A.

The cartridges, totally enclosed, contain the fuse wires proper and the incombustible powder which is not chemically affected by the rupture and, therefore, does not allow any overpressure to develop. The fuse wires are wound spirally on to a porcelain rod and are, thus, considerably longer than the length of the fuse-tube. Technical articles often mention that the rupturing capacity of the fuses is affected by the influence of the fuse-wire holding back the indication button. Brown Boveri tests confirm this, and avoid the said weakness by a special arrangement of the fuse-wire part holding back the indicating button, mentioned before.

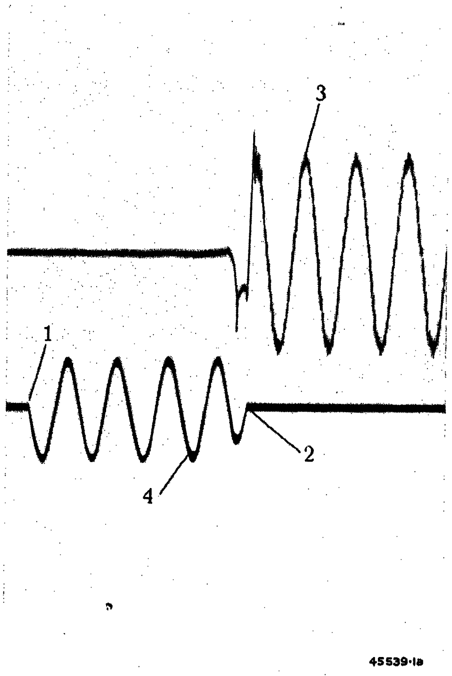


Fig. 3. — Oscillogram of the rupture of a low short-circuit current by a fuse, Type 11 kV, 10 A.

1. Beginning of overload.
2. End of rupture.
3. Recovery voltage 11 kV.
4. Current load 95 A.

The Brown Boveri fuse for indoor use is also suitable for outdoor plants and for the tropics, because it has no cemented joints and no water can penetrate into it. The end sleeves are pressed on to the porcelain tube and the end caps are held on by bayonet fastenings. There are strong springs inside the end caps which assure good contacts within the cartridge heads. Fuses which have blown can be repaired again by the plant operators without any special tools and without soldering. The end caps are removed by hand, the fuse wires are removed and the filling shaken out. The ceramic fuse-wire carrier is cleaned and new fuse wires wound on it; it is then remounted in the cartridge. The price of the extinguishing powder and the fuse wire is very low. Repair work does not take much more time than would be necessary to pack up and despatch damaged fuses. This work is accelerated by having a stock of ready-wound fuse-wire ceramic carriers. The Brown Boveri works, also, do repair work on fuses.

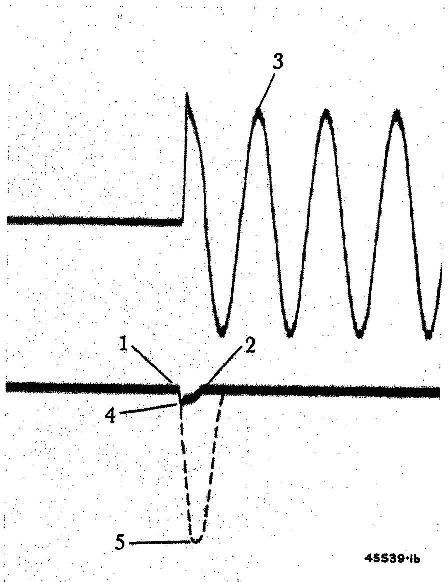


Fig. 4. — Oscillogram of the rupture of a heavy-current short circuit by means of a fuse, Type 11 kV, 10 A.

1. Beginning of short circuit.
2. End of rupture.
3. Recovery voltage 11 kV.
4. Highest current peak reached, 1500 A.
5. Short-circuit current of the plant (calculated) 15,200 A.

Fig. 2 shows cartridges for 6·4 and 37 kV. In order that even the biggest sizes of cartridge should remain clamped in their contacts, the clamping springs are made especially strong. On the other hand, it is unnecessary to provide any special protection against the dynamic effects of short-circuit currents because the fuse-wires melt and break so quickly that heavy currents have no time to build up. As the oscillogram of Fig. 3 shows, small over-currents are cut out after a few hundredth parts of a second. On the other hand, in the case of short circuits, the current is interrupted before it has built up completely, as the oscillogram of Fig. 4 shows very clearly. Thus, the new fuses protect very efficiently those parts of the plant on which they are placed both from damage due to dynamic forces of over-currents and to the thermal effects of short-circuit currents, thanks to the characteristics just mentioned.

The rupturing capacity is defined as the product of the current ruptured by the recovery voltage. The ruptured current of a fuse is the short-circuit current which may occur at the spot where the fuse is located if the fuse were to be replaced by some connection which would not melt. This definition allows the operating engineer to determine the type of fuse according to the same fundamental principles which he applies when closing a circuit breaker.

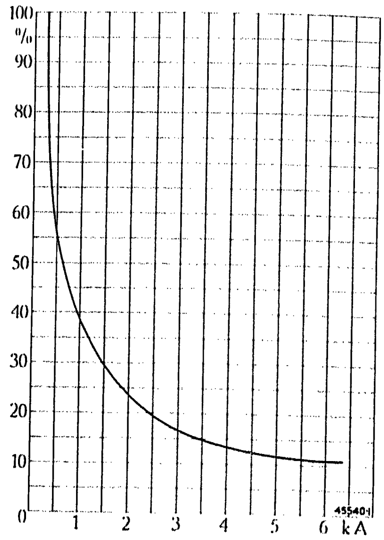


Fig. 5. — Limitation of the short-circuit current by a fuse

(average values measured).

Abscissae: Short-circuit current adjusted for so-termed rupture current.

Ordinates: Momentary value of max. current peak attained in % of value it would attain without a fuse.

The current which, really, occurs does not depend upon the characteristics of the system, solely, but also on the properties of the fuse, as is clearly seen in Fig. 5. The curve of Fig. 5 shows to what degree the building up of the full short-circuit current is suppressed by a fuse.

In order to combine the properties of the fuse with those of a disconnecting link, in a small space, a disconnecting fuse was designed (Fig. 6). In this case the cartridges are prevented from working loose through vibrations by means of bow-shaped latches. These latches can also be delivered for all other types of fuse supports and are always recommendable when the fuses are subjected to vibrations.

The fuse disconnectors are not suitable for the rupture of service currents; on the other hand, they can be used to cut low currents, like any other disconnecting link, such, for example, as the magnetizing current of small transformers. If, however, service currents or no-load currents of medium-size and big transformers have to be cut, then circuit breakers, only, must be used. The latter can be designed of low rupturing capacity

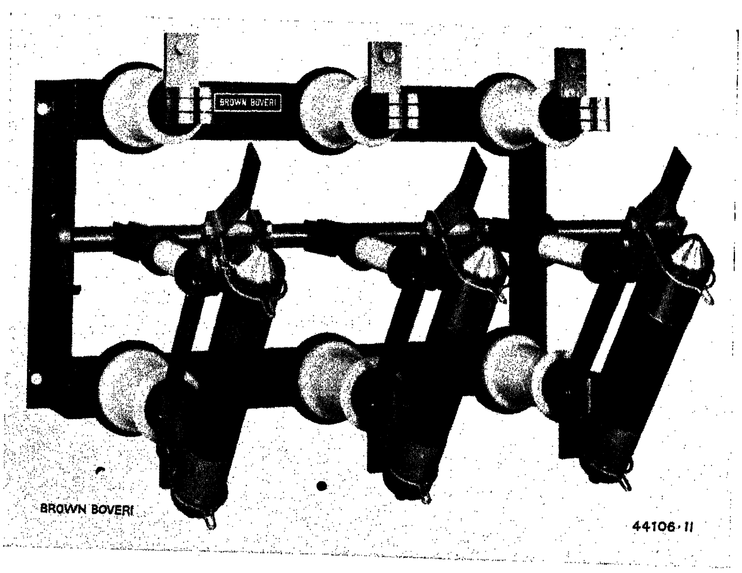


Fig. 6. — Three-pole fuse disconnector 11 kV with 20 A cartridges.

on condition that Brown Boveri high-capacity fuses are inserted in series with them. In this case, the fuses prevent heavy short-circuit currents building up while the breaker can handle moderate over-currents and ordinary service currents. To this end, it is also advantageous to put in an on-load disconnecting switch which can rupture some hundreds of amperes and takes up little space.

Fuses are, usually, only used to protect separate pieces of apparatus, motors or secondary branch lines, because the time they take to operate varies considerably, so that there is no question of precise selectivity with them and, also, because, they must be repaired on site after blowing out. Further, they are less suitable for heavy service currents because they then, loose a part of that most valuable property of suppressing the peaks of short-circuit currents.

Only circuit breakers with supervision by relays give selective protection and can take up duty again immediately after a tripping has occurred. Circuit breakers should, thus, be used on all important parts of the system the cutting out of which is undesirable for service reasons. If these factors are not of great importance and if only a reliable short-circuit protection is aimed at, the new Brown Boveri high-capacity fuses can be used to advantage, especially if this means leaving out an expensive high-power breaker.

(MS 561) *H. Müller. (Mo.)*

NOTES.

The rolling-leaf bridge at Oosterdoksluis, Amsterdam.

Decimal index 624.824 (492).

THE lines of the Dutch Railways cross the old Oosterdok lock before entering Amsterdam, the said lock being spanned by three leaf bridges. One of these was opened to service in May 1936, and the two others will be completed, shortly.

The first bridge opened to traffic (Fig. 1) and which is described in the following paragraphs, replaces an old turn bridge spanning the lock which is 20 m wide. The new bridge is of the leaf type and of quite a new design. There are toothed segments rigidly secured to each side of the girders forming the movable leaves of the bridge. These segments roll backwards or forwards on rails which are designed like racks, the teeth of the segments engaging in the notches of the racks. This movement causes opening and closing of the bridge. This design allows of leaving the whole breadth of the lock open to shipping when the bridge is in the open position, which is very advantageous to the water traffic. The two driving rods which move the segments are operated by winding gear and are seen in Fig. 1.

The chief characteristics of the bridge are:—

Total length	34·75	m
Width	9	m
Total weight	510	t
Height of two full-panelled girders	3	m
Length of the front part of the apron of the movable bridge	23·75	m

The front part is counterbalanced by a weight.

In order that the bridge should not move when trains cross it, it is securely locked when closed. This locking gear, also of quite new design, is composed in principle, of a cross bar and two movable wedge-shaped pieces actuated by it which are inserted under the land-side end of the bridge. A suitably designed rod transmission between the different parts of the locking gear assures smooth locking without shocks.

The entire mechanical part was delivered by the firm Ned. Dok Mij., in Amsterdam.

The winding gears for the closing and opening movements and for locking the bridge are, each, driven by a motor. In chosing the motors, it had to be born in mind that very big load fluctuations occur when the bridge is being opened or closed. The load torque — although varying — is always positive in the case of the locking gear, but this does not apply to raising and lowering the halves of the bridge. According to the direction and velocity of the wind, the load torques may be positive or negative, that is to say the moving leaves of the bridge may drive the motors. Therefore, the motor must be equipped for electric braking of the bridge leaves. Further, the special design used here for the locking gear made it necessary that the speed should be variable, over a wide range, so the locking operation should be accomplished without shocks and that the iron structure be as slightly stressed as is possible. It was also necessary to regulate the speed of the two leaves of the bridge over a wide range in order to obtain sufficient retardation at the end of the movement both at closing and at opening the bridge.

After a thorough investigation of the various driving systems which might have been suitable, the Dutch

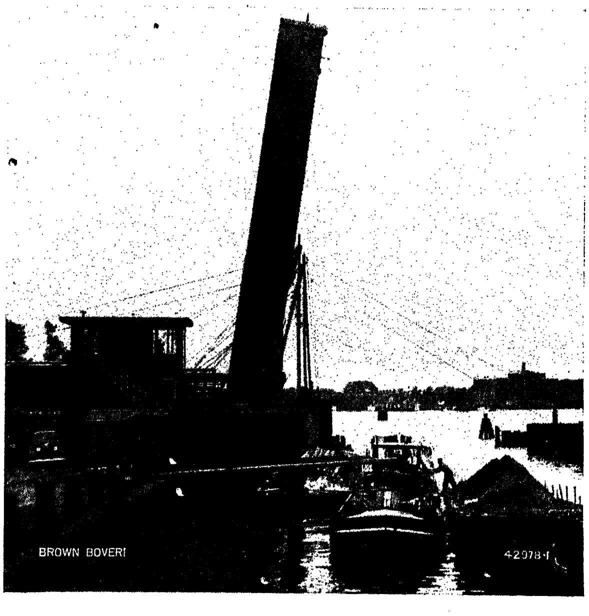


Fig. 1. — The rolling leaf bridge over the Oosterdoksluis at Amsterdam.
The bridge in open position.

Railways decided in favour of the three-phase shunt commutator motor of Brown Boveri design which meets all requirements as regards speed variation, electric braking and automatic service and, further, allowed of simplifying the plant and making it easy to supervise which means increasing its service reliability.

The three-phase shunt commutator motor of Brown Boveri design which has been frequently described, here, can be connected straight to the three-phase supply system. Its speed variations are perfectly smooth (no steps) and can be controlled over a wide range by simple displacement of the brushes; it is, practically, independent of the load torque. The shunt commutator motor takes up much less room than does a Ward-Leonard set, as only one machine is required instead of four; it calls for less upkeep and has a better efficiency. With these motors, electric braking is possible in all brush positions, that is at every speed and in super- as well as in sub-synchronous operation. If electric braking is resorted to, the motor runs as a generator and delivers power back to the supply system. The speed of the motor depends, solely, on the brush position and, practically, not at all on the load torque. Thus, inadmissible speeds cannot be attained and safety devices to meet this danger are not necessary. The shunt commutator motor is, thus, very suitable for automatic control equipments, where it is called for in order to simplify service, as in the plant under consideration.

The plant is supplied from a transformer of 100 kVA with three-phase current 380/220 V, 50 Hz. The motor for lifting the bridge leaves is designed for a rated output of 18 H. P. at 1440 r. p. m. and this speed can be varied down to 240 r. p. m. by regulation, the torque remaining the same, that is to say a ratio of 1 to 6 is attained. The rated output of the locking motor is 28 H. P. at 960 r. p. m. This speed, as well, can be regulated down to 240 r. p. m. giving a speed ratio of 1 to 4. Both motors are so wound that they can produce a big torque at starting, even if the supply voltage is rather too low. The motors are equipped with a small control motor for displacing the brushes and for automatic speed regulation.

It takes about two minutes to open or close the bridge and one minute to lock or unlock it. As great reliability is demanded of the bridge, because of the railway and water traffic, a spare drive has been provided for each movement which drives the bridge and locking gear at about 1/6 of the standard speeds. These auxiliaries are induction motors with squirrel-cage rotors of four and six H. P., respectively. In an emergency, they can be coupled up to the main drive, very quickly, by means of claw couplings.

The winding mechanisms for moving the leaves of the bridge and actuating the locking gear, along with their main and auxiliary motors and the apparatus belonging thereto, are located in a chamber inside the south pile below the driver's cabin, Fig. 2 shows a part of this machine room. The entire electric equipment is close to the canal and in very damp air. Therefore, it was necessary to have motors of drip-water proof design and to insulate the whole material, specially, against damp.

The apparatus for operating the bridge is lodged in a driver's cabin which is shown in Fig. 1. This cabin also contains the apparatus for assuring the safety of the trains and the control apparatus for the ship-traffic signals. All motors are operated by contactors, these are lodged in a switching cubicle along with the necessary relays for protecting the motors. There is a switchboard desk which contains all the control apparatus, such as push-buttons, rotary switches, etc. as well as the signal lamps for supervising the signals. The simple and clear layout of this desk makes the work of the operators much simpler and allows of constant supervision of the whole plant. Further, there is a series of end-travel switches which limit the end-travel positions of the bridge and locking gear and which also intervene automatically when it is requisite that the speed of the various drives should be altered. Thus, the control is semi-automatic, that is to say, the bridge is started up, accelerated, slowed down and stopped in the end-travel positions without it being necessary for the operators to intervene. Therefore, service is limited to actuating the different signals and push-buttons for the opening and closing of the bridge. Of course, this plant is equipped with all the necessary safety devices to allow of perfect service combined to great reliability.

It is interesting to note that the mechanical brakes are not controlled by brake-releasing electro-magnets but by the new Brown Boveri electro-hydraulic thrustors. The smooth operation and adjustable damping characteristics of this apparatus is especially advantageous in the case of a draw bridge of this kind.

The complete electrical equipment was delivered by Brown Boveri and handed over ready for service. Since starting up, the plant has worked to the entire satisfaction of the Dutch Railways.

(MS 566)

G. Rochat. (Mo.)

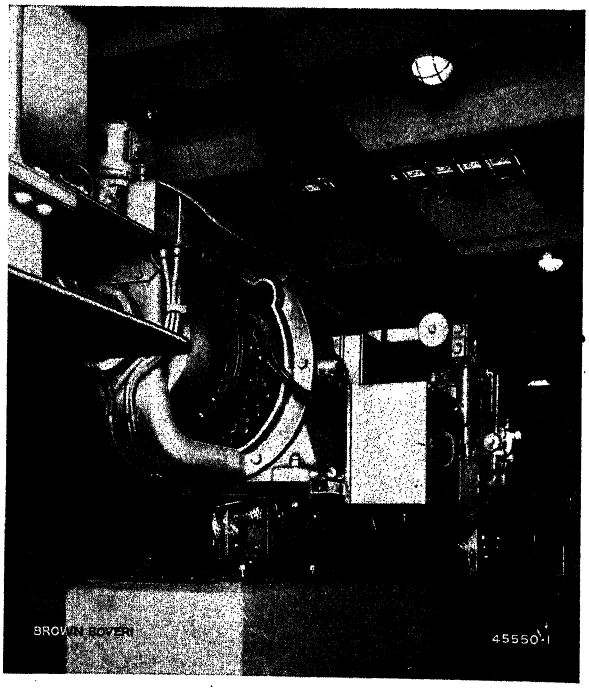


Fig. 2. — Partial view of machine room containing the winding mechanism.
In the foreground, the driving motor of the locking gear, in the background, the electro-hydraulic thrustor for brake lifting.

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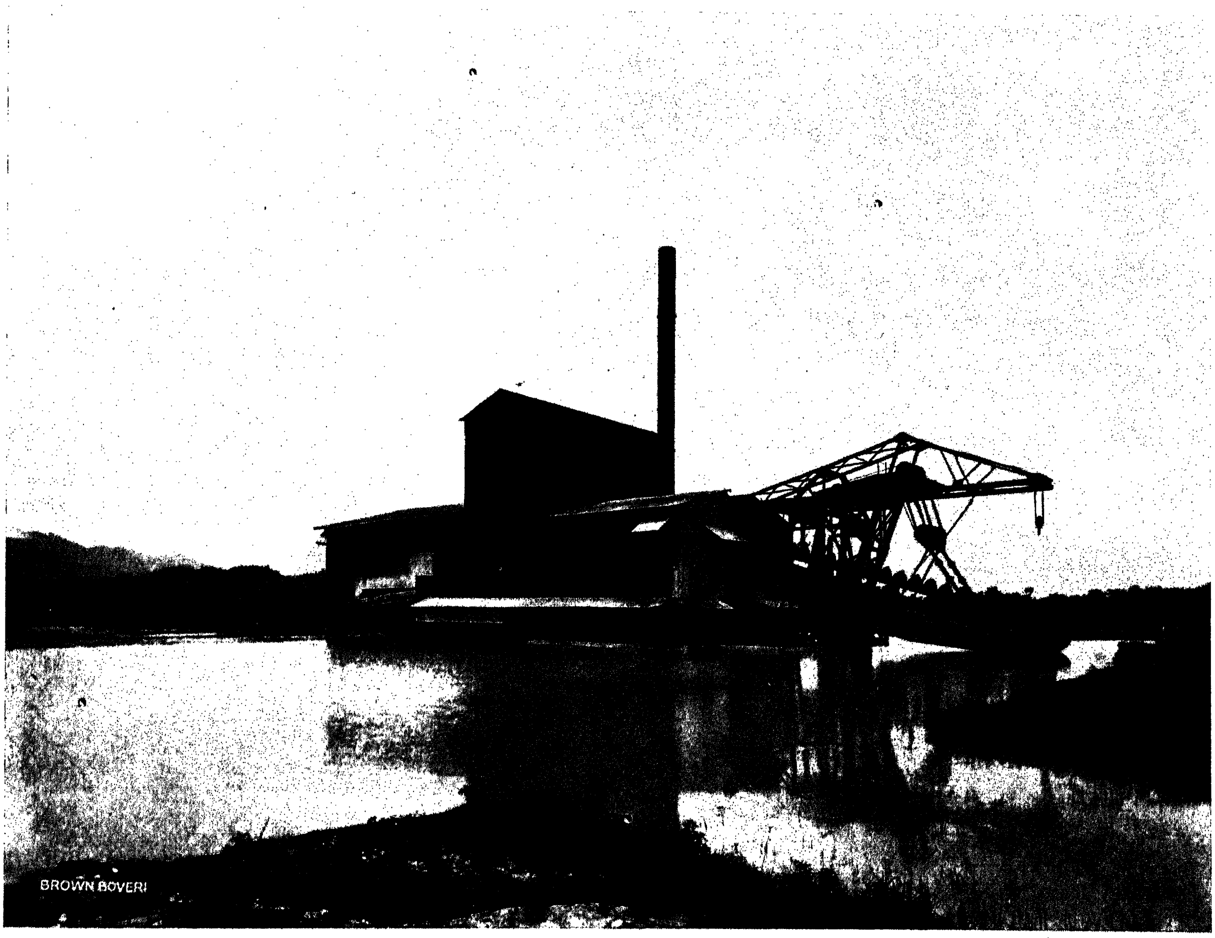

FLOATING DREDGER FOR TIN DREDGING BELONGING TO THE LARUT TIN FIELDS LTD., TAIPING (FEDERATED MALAY STATES), EQUIPPED WITH A 500-KW THREE-PHASE TURBO-SET OF BROWN BOVERI DESIGN.

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VOLTAGE REGULATION.

THE BROWN BOVERI ON-LOAD TAP-CHANGING SWITCH FOR NEUTRAL-POINT VOLTAGE REGULATION.

Decimal index 621.316.722.

I. INTRODUCTION.

CONSIDERED from the technical point of view, maintenance of frequency and regulation of voltage are to be considered as being the fundamental factors of any planned power-supply system.

It is the duty of *voltage regulation* to provide and maintain the voltage in the various parts of the system so that the requirements of power consumers, as regards constant voltage, are as perfectly met as is possible. At the same time, in the case of parallel supply, the reactive load is influenced by voltage regulation, so that, under certain conditions, this distribution of reactive load has to be kept in mind.

The most common solutions of the voltage-regulation problems are:—

(a) Maintenance of the voltage by means of the generators in the various power stations.

(b) Adjustment of the voltage at the terminals of transformers having taps, this in the power stations, substations and in consumer's plants.

(c) Regulation of the voltage at the terminals of transformers equipped with on-load tap-changing switches in the power stations, substations and in consumer's plants.

(d) Regulation of the voltage by means of rotary transformers (simple and double induction regulators).

(e) Regulation of the voltage by modifying the distribution of the reactive load, by means of static condensers, also by using rotating synchronous and asynchronous condensers.

Of these various solutions of the problem, which may be used either singly or in combination with one another, by far the most commonly employed is that of the on-load regulation by transformers equipped with taps. Although this means a regulation in steps, it has been found that, if the taps are close enough, the resulting regulation, step by step, does not present any disadvantage. Further, as regards utilization of material, space taken up, reliability of operation, supervision and upkeep, this type of regulation is so advantageous that whatever small disadvantages it may have can be tolerated.

The requirements made on tap switches as regards number of taps, current and voltage range, surge-proof strength against the effects of travelling waves, reliability, easy dismantling for freighting grow increasingly severer. It is not sufficient that power stations should increase their distribution systems and link up to other sources of supply in order to meet constantly increasing demands for power, over and above these measures, they are forced to raise the service reliability of their plants by improving the quality of the equipment. In order to meet the severer requirements in question, it became necessary to enlarge the existing range of tap switches by other types.

However, before touching on the field of on-load tap-changing switches developed by Brown Boveri, some problems belonging to the field of regulation should be examined.

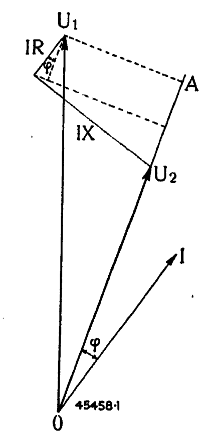


Fig. 1. — Diagram to determine the voltage U_2 at the end of a transmission system, for a given voltage U_1 at the origine of the system.
$U_1A = JX \cos \varphi - JR \sin \varphi$.
$U_2A = JR \cos \varphi + JX \sin \varphi$.

II. DETERMINATION OF THE VOLTAGE DROP.

The *voltage drop* of the generators is, usually, compensated for by modifying the excitation. Therefore, the voltage on the generator bus-bars can be assumed to be constant. From the generator bus-bars up to the points of consumption, the voltage changes by the amount of voltage drop in the transformers and transmission lines.

This voltage drop can be determined by

$$\Delta U = U_1 + JR \cos \varphi + JX \sin \varphi - \sqrt{U_1^2 - (JX \cos \varphi - JR \sin \varphi)^2} \quad \ldots (1)$$

This formula is valid for a circuit characterized by:—

R = Ohmic resistance, per phase, in ohms.
X = Inductive resistance per phase, in ohms.
φ = Angle of phase displacement of load at end of circuit, in degrees.

U_1 = Phase voltage at beginning of circuit, in volts.
U_2 = Phase voltage at end of circuit, in volts.
J = Current, in amperes.

(a) *Determination of the voltage* U_2 (diagram as per Fig. 1), when U_1 is known.

$$U_2 = \sqrt{U_1^2 - (JX\cos\varphi - JR\sin\varphi)^2} - (JR\cos\varphi + JX\sin\varphi) \quad \ldots (2)$$

(b) *Determination of the voltage* U_1 (diagram as per Fig. 2), when U_2 is known.

$$U_1 = \sqrt{(U_2\sin\varphi + JX)^2 + (U_2\cos\varphi + JR)^2} \quad \ldots (3)$$

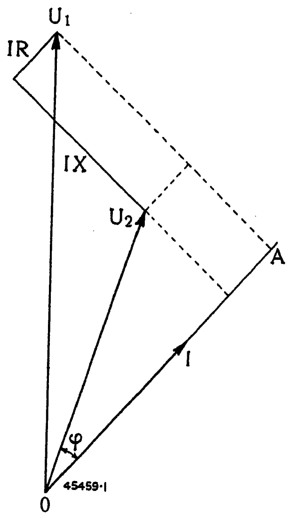


Fig. 2. — Diagram to determine the voltage U_1 at the origine of a transmission system, for a given voltage U_2 at its end.
$U_1A = U_2\sin\varphi + JX$.
$OA = U_2\cos\varphi + JR$.

Very frequently, the ohmic and inductive components of the voltage drop are reckoned in percentages and referred to the known voltages U_1 (U_2) at the beginning (end) of the system.

Assuming

$$\frac{JR}{U_1} = \frac{p_1}{100} \quad \frac{JX}{U_1} = \frac{q_1}{100}$$

$$\frac{JR}{U_2} = \frac{p_2}{100} \quad \frac{JX}{U_2} = \frac{q_2}{100}$$

the following result is attained for the equations (2) and (3):—

$$U_2 = U_1\left\{\sqrt{1 - \left(\frac{q_1}{100}\cos\varphi - \frac{p_1}{100}\sin\varphi\right)^2} - \left(\frac{p_1}{100}\cos\varphi + \frac{q_1}{100}\sin\varphi\right)\right\} \quad \ldots (4)$$

$$U_1 = U_2\sqrt{\left(\sin\varphi + \frac{q_2}{100}\right)^2 + \left(\cos\varphi + \frac{p_2}{100}\right)^2} \quad \ldots (5)$$

Ohmic resistance and inductive reactance of the system can be ascertained from these same magnitudes valid for the various elements making up the system.

When two elements are in series

$$\left.\begin{array}{l} R = R_1 + R_2 \\ X = X_1 + X_2 \end{array}\right\} \quad \ldots (6)$$

If the elements are, on the contrary, in parallel

$$\left.\begin{array}{l} R = \dfrac{R_1(R_2^2 + X_2^2) + R_2(R_1^2 + X_1^2)}{(R_1 + R_2)^2 + (X_1 + X_2)^2} \\ X = \dfrac{X_1(R_2^2 + X_2^2) + X_2(R_1^2 + X_1^2)}{(R_1 + R_2) + (X_1 + X_2)^2} \end{array}\right\} \quad \ldots (7)$$

For several elements connected in series or in parallel, the above equations can be enlarged by introducing the proper magnitudes for the problem under consideration.

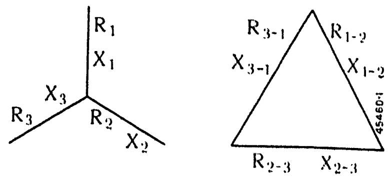


Fig. 3. — Transformation of a star into a delta connection.

Finally, in order to *transform a star connection* composed of three elements into a delta connection (Fig. 3) the following equations are used:—

$$\left.\begin{array}{l} R_{1-2} = R_1 + R_2 + \dfrac{R_1R_2R_3 - R_3X_1X_2 + R_1X_2X_3 + R_2X_3X_1}{R_3^2 + X_3^2} \\ R_{2-3} = R_2 + R_3 + \dfrac{R_1R_2R_3 - R_1X_2X_3 + R_2X_3X_1 + R_3X_1X_2}{R_1^2 + X_1^2} \\ R_{3-1} = R_3 + R_1 + \dfrac{R_1R_2R_3 - R_2X_3X_1 + R_3X_1X_2 + R_1X_2X_3}{R_2^2 + X_2^2} \\ \text{and} \\ X_{1-2} = X_1 + X_2 + \dfrac{X_1X_2X_3 - X_3R_1R_2 + X_1R_2R_3 + X_2R_3R_1}{R_3^2 + X_3^2} \\ X_{2-3} = X_2 + X_3 + \dfrac{X_1X_2X_3 - X_1R_2R_3 + X_2R_3R_1 + X_3R_1R_2}{R_1^2 + X_1^2} \\ X_{3-1} = X_3 + X_1 + \dfrac{X_1X_2X_3 - X_2R_3R_1 + X_3R_1R_2 + X_1R_2R_3}{R_2^2 + X_2^2} \end{array}\right\} \quad (8) \ldots$$

Conversely, it is often necessary to transform a *delta connection* into a star one. The equations corresponding to this conversion are (Fig. 4).

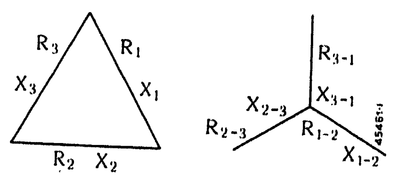


Fig. 4. — Transformation of a delta into a star connection.

$$\left.\begin{array}{l} R_{1-2} = \\ \dfrac{(R_1+R_2+R_3)(R_2R_3 - X_2X_3) + (X_1+X_2+X_3)(R_2X_3 + X_2R_3)}{(R_1+R_2+R_3)^2 + (X_1+X_2+X_3)^2} \\ R_{2-3} = \\ \dfrac{(R_1+R_2+R_3)(R_3R_1 - X_3X_1) + (X_1+X_2+X_3)(R_3X_1 + X_3R_1)}{(R_1+R_2+R_3)^2 + (X_1+X_2+X_3)^2} \\ R_{3-1} = \\ \dfrac{(R_1+R_2+R_3)(R_1R_2 - X_1X_2) + (X_1+X_2+X_3)(R_1X_2 + X_1R_2)}{(R_1+R_2+R_3)^2 + (X_1+X_2+X_3)^2} \\ \text{and} \\ X_{1-2} = \\ \dfrac{(R_1+R_2+R_3)(R_2X_3 + X_2R_3) - (X_1+X_2+X_3)(R_2R_3 - X_2X_3)}{(R_1+R_2+R_3)^2 + (X_1+X_2+X_3)^2} \\ X_{2-3} = \\ \dfrac{(R_1+R_2+R_3)(R_3X_1 + X_3R_1) - (X_1+X_2+X_3)(R_3R_1 - X_3X_1)}{(R_1+R_2+R_3)^2 + (X_1+X_2+X_3)^2} \\ X_{3-1} = \\ \dfrac{(R_1+R_2+R_3)(R_1X_2 + X_1R_2) - (X_1+X_2+X_3)(R_1R_2 - X_1X_2)}{(R_1+R_2+R_3)^2 + (X_1+X_2+X_3)^2} \end{array}\right\} \quad (9) \ldots$$

The ohmic resistance of lines is determined by the material, sections, lengths and temperature. It is

$$R = \rho \left\{ 1 + \alpha (t - 20) \right\} \frac{l}{F} \quad \ldots (10)$$

The above designations are:—

R = Resistance of conductor, in ohms, at temperature t.
ρ = Specific resistance (t = 20° C).
α = Temperature coefficient.
t = Temperature of conductor, in ° Celsius.
l = Length of conductor, in metres.
F = Section of conductor, in mm².

Between conductor-section F and conductor-radius r there is the following relation:—

$$\left.\begin{array}{l} \text{for wires } F = \pi r^2 \\ \text{for cables } F = 0{\cdot}77\, \pi r^2 \end{array}\right\} \quad \ldots (11)$$

The following Tables I and II give the resistances per km of conductor length for standard wires and cables.

TABLE I.

Wires.		Material: Copper
Rated section mm²	Diameter mm	Resistance at t = 20° C ohms/km
6	2·75	3·0
10	3·55	1·8
16	4·5	1·1

TABLE II.

Cables.
Material: 1. Copper, 7—61 wires
2. Steel, aluminium { steel 1—7 wires; aluminium 6–26 wires }

Rated section	1			2			
	Number of wires	Diameter	Resistance at t = 20° C	Number of wires: Steel	Number of wires: Aluminium	Diameter	Resistance at t = 20° C
mm²		mm	ohms/km			mm	ohms/km
10	7	4·1	1·78	—	—	—	—
16	7	5·1	1·12	1	6	5·4	1·9
25	7	6·3	0·74	1	6	6·8	1·22
35	7	7·5	0·53	1	6	8·1	0·85
50	7 19	9 9	0·364 0·372	1	6	9·6	0·6
70	19	10·5	0·271	7	26	11·6	0·438
95	19	12·5	0·192	7	26	13·4	0·322
120	19	14	0·153	7	26	15·7	0·237
150	37	15·8	0·121	7	26	17·3	0·195
185	37	17·5	0·098	7	26	20·5	0·139
210	—	—	—	7	26	20·5	0·139
240	37 61	19·6 20·3	0 078 0·074	7	26	21·7	0·123
300	61	22·5	0·06	7	26	24·2	0·098

Copper: $\varrho = 0{\cdot}0178$, $\alpha = 0{\cdot}004$ Aluminium: $\varrho = 0{\cdot}029$, $\alpha = 0{\cdot}0037$

The ohmic resistance of transformer windings can be determined from the copper losses at full load and at p. f. = 1 with the help of the following equation:—

$$R = 1000\, V_{cu} \left(\frac{U\sqrt{3}}{P} \right)^2 \quad \ldots (12)$$

in which:—

R = Resistance per phase, in ohms.
V_{cu} = Copper losses at full load and p. f. = 1, in kW.
U = Phase voltage in kV.
P = Load (three-phase) in kVA.

The inductive reactance of lines depends on the layout and dimensions of the lines. For a three-phase simple line, either overhead or cable

$$X_I = 0{\cdot}1446 \log. 1{\cdot}29 \frac{d_1}{r} \quad (13)$$

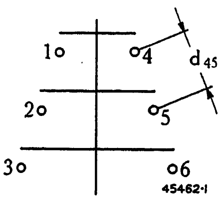


Fig. 5. — Mast diagram of a double line.

For a double line with two conductors on the same masts (Fig. 5) the equation is:—

$$X_{II} = \frac{1}{2} \cdot 0{\cdot}1446 \log. 1{\cdot}29 \frac{d_1}{r} \frac{d_2}{d_3} \quad \ldots (14)$$

in which

X_I, X_{II} = Reactance per phase, in ohms, per km, at 50 cycles.
log. = Logarithm with basic number 10.
d_1, d_2, d_3 = Geometrical average of distance between conductors in cm.

$$d_1 = \sqrt[3]{d_{12} \cdot d_{23} \cdot d_{31}}$$

$$d_2 = \sqrt[3]{d_{15} \cdot d_{26} \cdot d_{34}}$$

$$d_3 = \sqrt[3]{d_{14} \cdot d_{25} \cdot d_{36}}$$

r = Radius of conductor in cm.

It should be noted that the equation refers to the positive-sequence reactance, that is to say to the reactance which is valid for the voltage drop under three-phase symmetrical loading of the line. The reactance is independent on the clearance between line and ground.

The *inductive reactance of transformers* can be ascertained directly from the short-circuit voltage of the transformer. If:—

X = Reactance per phase, in ohms.
Z = Impedance per phase, in ohms.
R = Ohmic resistance per phase, in ohms.
e_k = Short-circuit voltage, in %.
U = Phase voltage, in kV.
P = Load (three-phase), in kVA.

the following equations are valid for the reactance:—

$$Z = 1000 \frac{e_k}{100} \frac{(U\sqrt{3})^2}{P} \quad \ldots (15)$$

and

$$X = \sqrt{Z^2 - R^2} \quad \ldots (16)$$

In Fig. 6, the short-circuit voltage in function of the load is given for transformers of standard design. Deviations therefrom, of greater or lesser importance, must, of course, be reckoned with in the case of variations in transformer design, different arrangements of the windings etc. Account must be taken of the voltage differences caused by the *magnetizing currents of the transformers* and by the *charging currents of the system*, when exact calculations of the voltage drop are carried out. In so doing, the voltage drop caused by the magnetizing current in the line and that of the charging current in the transformers has to be determined according to equation (1). The voltage drop caused by the magnetizing current in the transformer itself can be introduced into the calculation approximately by using the following relation:—

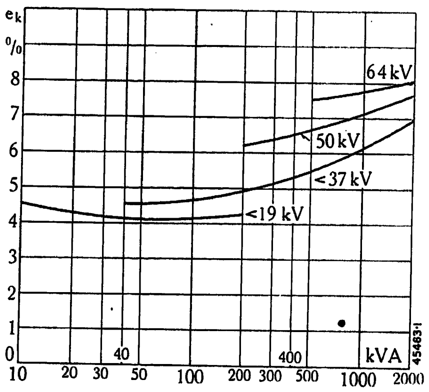


Fig. 6. — Short-circuit voltage in function of the output, in the case of transformers of standard design.

$$\Delta U_T \cong {}^1/_2\, J_m X_T \quad \ldots (17)$$

A similar equation for the voltage drop on a line caused by its charging current is:—

$$\Delta U_L \cong -{}^1/_2\, J_c X_L \quad \ldots (18)$$

The approximations which result therefrom are quite sufficient for power transmission with voltages up to 100 kV and lengths of line up to 100 km. The values designated are as follows:—

ΔU_T (ΔU_L) = Voltage drop per phase in transformer (on line), in volts.
J_m = Magnetizing current of transformer, in amperes.
X_T = Reactance of transformer per phase, in ohms.
J_c = Charging current of line, in amperes.
X_L = Reactance of line per phase, in ohms.

The different solutions used for voltage regulation were summarized in the introduction. The following paragraphs go into the said regulating methods with the object of showing their pros and cons, and of delimiting their fields of application more or less sharply.

III. METHODS OF REGULATING THE VOLTAGE.

(a) *The voltage regulation of the generators.* Voltage regulation on the generators in the power station is, generally, confined to the maintenance of the voltage, either across the terminals of the generators, or on the generator bus-bars, or else on the high-voltage side of the transformers. Practically always, generators, including those of smaller output, are equipped with quick-acting regulators the duty of which is to maintain the voltage constant, automatically. A stabilization system is necessary in order to attain a proper distribution of the reactive load among units operating in parallel, when automatic regulation to constant voltage is utilized. When static regulators are used, it is possible to arrive at an entirely satisfactory solution as regards the distribution of reactive load by means of stabilization compounding to compensate the voltage drop. This has the further advantage of great simplicity. The connections are given in Fig. 7. If, for any reason, this solution cannot be utilized, as, for instance, if supercompounding of the voltage is called for, or if there is no suitable current available for the phase, to compensate the static feature of the regulator (such as happens in single-phase plants), it is possible to make use of astatic regulators and to attain perfectly satisfactory results. The load current is called into use, here, in order to stabilize the reactive load distribution. The stabilizing transformers are connected in polygone, in the manner shown in Fig. 8.

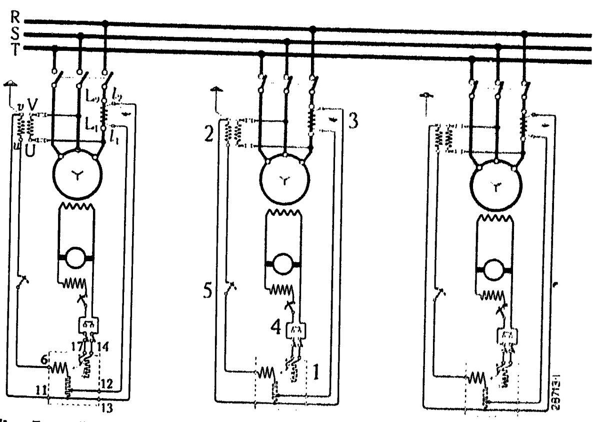


Fig. 7. — Voltage regulation for generators operating in parallel with static regulators.

The regulation of the voltage at the generator terminals or power-station transformer terminals, with the object of maintaining constant voltage at the consumer end, is not recommendable for various

reasons. To begin with, the voltage drops from the power station up to the various centres of power consumption vary very much. The differences must be equalized and, to this end, an additional regulation system must be inserted on the network. This last regulating system can, however, itself, undertake the duty of keeping the consumer voltage constant.

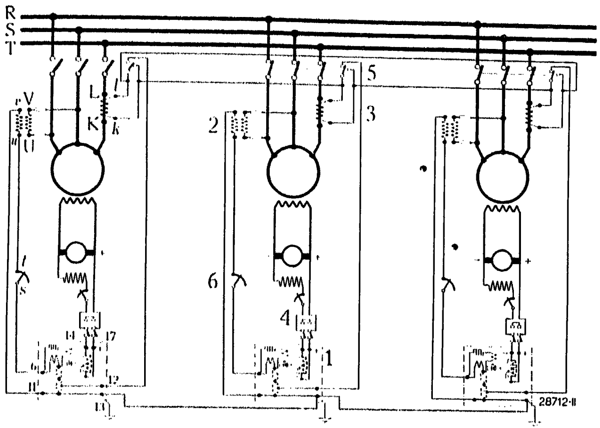


Fig. 8. Voltage regulation for generators operating in parallel with astatic regulators.

Further, it must be remembered that the number of coil turns of the generator winding connected up to the system cannot be altered so that the whole duty of regulating falls on altering the excitation, that is on variation of the induction. But these variations in induction can only take place over a narrow range, because they are limited, in the upward sense by saturation and in the downward sense by the limit of stability in parallel service. In order not to exceed these limits the requirement of a bigger range of regulation means using bigger generators. This leads to a solution of the problem which is inacceptable from the economical point of view.

When the voltage in the power station is maintained constant, there is only the voltage drop in the transformers and in the system to be compensated by inserting regulating devices. It should be said, first, that the regulation has the object to maintain the voltage at the consumer's plant as constant as possible. A compensation of the voltage drop, for itself alone, is not necessary, when care is taken that the said drop does not vary. The setting of the correct consumer's voltage can then be attained by the choice of the proper transformation ratio for the transformers. Thus, all efforts to get power stations to fill up the inequalities in their load charts also implies creating better voltage relationships between power houses and consumption centres. On the other hand, it must be remembered that, even when there is a satisfactory equalization of load in the power station, it may happen that the load — and, therewith, the voltage — in the substations may fluctuate considerably. For this reason, the maintenance of voltage by the generators must be completed by a voltage regulation on the network.

There are two fundamentally different methods which may be made use of to solve the problem of voltage regulation on a system and these methods can be used separately or in conjunction with each other. The first is that of *voltage regulation by the influencing of the transmission of reactive load.* The second method is that of the *introduction of an additional voltage in series with the system voltage.*

(b) *Voltage regulation by transmission of reactive load.*—The equation (1) for the voltage drop

$$\Delta U = U_1 + JR\cos\varphi + JX\sin\varphi - \sqrt{U_1^2 - (JX\cos\varphi - JR\sin\varphi)^2}$$

shows that the loss, apart from the magnitude of the load current, is also dependent on its direction. This is shown more clearly by the equation

$$\Delta U \cong JR\cos\varphi + JX\sin\varphi \qquad \ldots (19)$$

This equation can only be used, however, for very approximate calculations, because the errors, referred to the system voltage, become considerable for relatively small angular displacements of the voltage vector (angle Θ between U_1 and U_2). The errors are given in function of angle Θ in Fig. 9. For a 10 % drop and $\Theta = 10^0$, the error already attains 1·5 % referred to the system voltage and 15 % referred to the voltage drop itself.

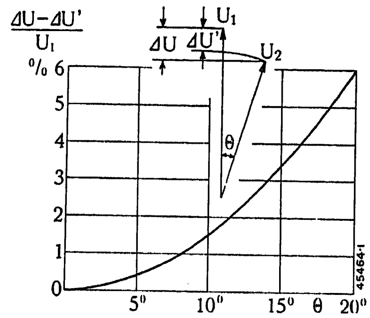


Fig. 9. — Errors in the calculation of the voltage drop according to the equation $\Delta U = JR\cos\varphi + JX\sin\varphi$ in function of the angular displacement Θ of the voltage vector.

From consideration of equation (19) in the following form:

$$U \cong (J\cos\varphi)R + (J\sin\varphi)X \qquad \ldots (20)$$

it will be apparent that with constant active power ($J\cos\varphi$), the voltage drop can be regulated over a wide range by changing the reactive load ($J\sin\varphi$). At the points of the system where the voltage is too low, the voltage drop can be reduced from the value (ΔU) to $(\Delta U)_1$ by feeding in reactive current (J_1). The reduced voltage drop is given by:—

$$(\Delta U)_1 \cong (J\cos\varphi)R + (J\sin\varphi - J_1)X \ldots (21)$$

It is possible to eliminate the voltage drop completely, in this way and even to transform it into a voltage rise. To this end, the following reactive currents are required.

$J_1 \cong J \sin\varphi + (J\cos\varphi)\frac{R}{X}$ for equality of voltages (drop = 0)

$J_1 > J \sin\varphi + (J\cos\varphi)\frac{R}{X}$ for voltage increase (negative drop)

Static or rotary condensers (synchronous and asynchronous phase compensators) can be used for supplying the reactive current required. The rotary machines have the advantage of allowing the setting, at will, of the reactive-current supply, within the load limits of the respective machines, working either as consumers or generators as desired; the machine being under- or over-exerted to this end. Another advantage is the close regulation possible by means of the field rheostat. On the other hand, the static condensers have the advantage of lower losses. As there are no rotary masses in this type of condenser, there are no foundations required, there is no noise and there is less supervision called for than in the case of rotating machinery.

In the case of voltage regulation by means of choke coils, which are summarily mentioned here in order that the entire field should be covered, the method utilized is also that of an influencing of the reactive-load transmission. However, as referred to the natural voltage characteristic recorded from full to no load, the voltage can only be regulated downwards, in this way. While, in the methods of regulation already mentioned here, it is quite possible to regulate the voltage to a value equal to the no-load figure, the utilization of regulating choke coils allows, at the most, constant maintenance of full-load voltage (Fig. 10). For this reason, choke coils are used more to compensate voltage peaks which are a characteristic of the capacities of high-voltage overhead transmission lines and also of high-voltage cable connections rather than for pure regulation of voltage.

The method of voltage regulation by the superimposing of a reactive load can only be used to advantage in cases where the reactive current flows over sufficiently big inductive reactances in its circuit. This condition is fulfilled when there are transformers on the transmission system the reactances of which not only correspond to long lengths of line but for which the ratio $\frac{X}{R}$ is big, that is to say advantageous. From the curve in Fig. 11 for standard-design transformers, the ratio $\frac{X}{R}$ can be read off in function of the transformer load. Of course, deviations in both senses are possible.

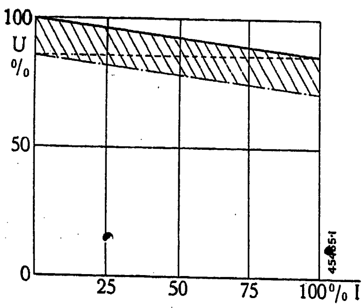


Fig. 10. — **Voltage regulation by choke coils.**
----- Regulation to constant voltage.

If the reactances are not available or if the ratio $\frac{X}{R}$ is too small the regulating method in question cannot be used. When, for example, two systems are to be coupled which have different voltages, by means of a short length of line, without transformers, the method of voltage equalization by reactive-load transmission would not be economical.

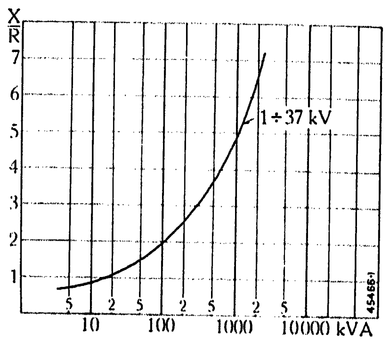


Fig. 11. — **Relationship between inductive reactance and ohmic resistance with transformers of standard design, in function of the load.**

(c) *Voltage regulation by the introduction of an additional voltage.* — The additional voltage can be produced in different ways, thus by the rotating stator field of a rotary transformer, by the main flux in a regulating transformer (series excitation) or by the flux of a separate excitation transformer (shunt excitation). The various connections are shown in Fig. 12.

Regulation of the voltage with the single type

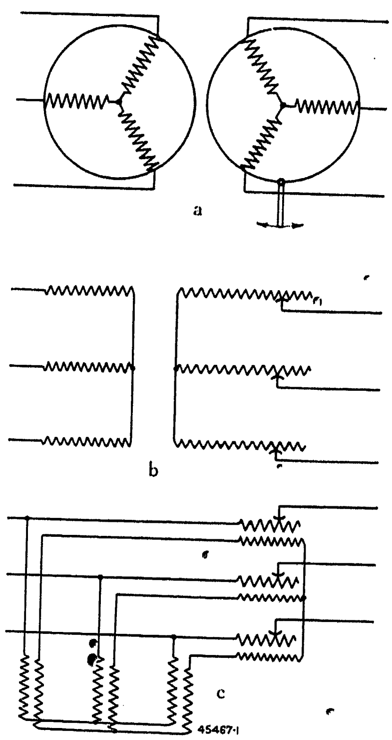


Fig. 12. — **Different diagrams to create an additional voltage.**

a. By the rotating field of an induction regulator.

b. By the main flux of a regulating transformer.

c. By a series transformer with separate excitation.

of induction regulator is carried out by turning the rotor, through a certain angle; this displaces the phase of the induced additional voltage in the rotor as compared to the phase of the system, within given limits (usually between 0 and 180°). However, this phase displacement is not allowable in all cases, and this is especially so when the additional voltage works in a closed-ring system or on parallel lines. By phase displacement, the active load distribution is influenced, in the case of a closed circuit. This disturbing feature can be eliminated by the series connection of two simple regulators. These have to be mechanically coupled and have, one, a displacement of the additional voltage to the left, the other, to the right.

The field of utilization of the single and double type of induction regulator is limited, in practice, by the highest voltage for which these regulators can be built, this being about 10 to 15 kV, according to output. As soon as the voltage of the system exceeds these values, the transformer coupling of the regulator with the system is the only solution, but it is uneconomical, because of the amount of material it calls for. The advantages of regulation with the help of induction regulators are smooth variation of the voltage and the possibility of rapid regulation by making use of oil-pressure control.

IV. THE REGULATING TRANSFORMER.

There are a series of regulating questions to be investigated when designing a regulating transformer. These questions concern:—

(a) The connections of the transformer (auto-connection or with separate windings).
(b) Its regulation to be on the high- or low-voltage side.
(c) The magnitude of the voltage step employed.

(a) *Connections.* — The choice of connections depends on whether it is an existing plant, into which the regulation gear is built, in order to improve voltage conditions, or if it is a quite new plant, allowing of utilizing the main transformers as regulating transformers. In the first case, efforts are made to lodge the regulation proper in a series transformer with winding in auto-connection, in order to keep first costs low. Here, it must be born in mind, that the relatively low short-circuit strength of an auto-transformer may make it necessary to insert short-circuit limiting coils before the said transformer. The design of the transformer with separate windings has, also, the advantage that it permits of the free choice, within certain limits, of the phase angle between the low and the high voltage-side voltage vectors, this by using a suitable winding connection. This may be necessary on account of there being parallel operation to be carried out with existing transformers. Further, the two-winding transformer in delta/star or delta/zigzag connection offers the possibility of loading the transformer neutral point without deforming the voltage diagram too much, as happens in the case of a transformer, in auto-connection.

(b) *Regulation.* — Generally speaking, the following factors play a part in the choice of regulation, either on the high or on the low-voltage side of the transformer:—

The system of winding connections,
the regulating conditions,
the current and voltage limits of the tap-changing switch already designed.

In special cases, other points of view may play a part, such, for example, as the way the tap-changing switch is lodged in the transformer, the earthing method used for the neutral point of the system, etc.

Among the systems of connection, star connection is the most suitable for building in a tap-changing switch. The development of a three-pole on-load tap-changing switch is an example of technical progress made last year and the relegation of regulation to the star point of the winding. Of course, this solution can only be used with star connection.

Delta connection imposes the use of single-pole step switches in all phases. In order to avoid a distortion of the voltage diagram, it is necessary to carry out regulation inside the triangle of the delta connection. This is very disadvantageous as far as the space taken up in the transformer is concerned, as it means three further bushings in order to carry out the delta connection outside the tank, on the transformer cover.

The most disadvantageous of all is the building in of tap-changing switches with the zig-zag transformer connection. The winding design with two windings per column leads to a doubling of the number of tap-changing switches or to a combination of three phases and a star-point tap-changing switch.

Apart from the connections of the winding, the regulating conditions specified are often a factor to be taken into account in the choice of the side (high or low-voltage side) chosen for building in the tap-changing switches. It is advantageous to put in the regulation on the side where there are the biggest voltage fluctuations, therefore, mostly on the incoming side.

The first costs of tap-changing switches for very high voltages or strong currents are considerably higher than those of tap-changing switches for average current and voltage ranges. Further, it must be taken into account that the said switches designed for extreme values are not only more difficult to make but take up more room when built in; they are not so easy to handle at erections and, finally,

have, generally, only a relatively small number of steps, this for constructive reasons.

(c) *Magnitude of the voltage steps.* — The voltage steps should not exceed about 1·5 % of the rated voltage, as shown by practice, this when the transformer is used to supply low-voltage systems with lighting duty. In the case of coupling transformers and those for purely power supply, step voltages of 2—3 % are, still, acceptable.

V. DESCRIPTION OF THE ON-LOAD TAP-CHANGING SWITCH.

(a) *Tap-changing switch inserted on the phase, Types H and HF.* — The principle organs of the on-load tap-changing switch are:—

The selector,
the sparking switch,
the bridging resistance,
the bushing.

Fig. 13 shows a three-pole on-load tap-changing switch for 64 kV and 400 A. The bushing insulator carries, at its lower end, an insulating cylinder with contacts mounted on its inner side, parallel to the axis of the cylinder. The current collector with double brush runs over these contacts. Both brushes are driven simultaneously by a worm gear through concentrically-located shafts.

The movement of the brushes is alternative. First, one brush moves round from one contact to its neighbour; during this time, the second brush is immobile. Then the second brush moves round through the same angle as the first one, so that, finally, both are together again. As compared to the original position, the selector has, now, moved round by one

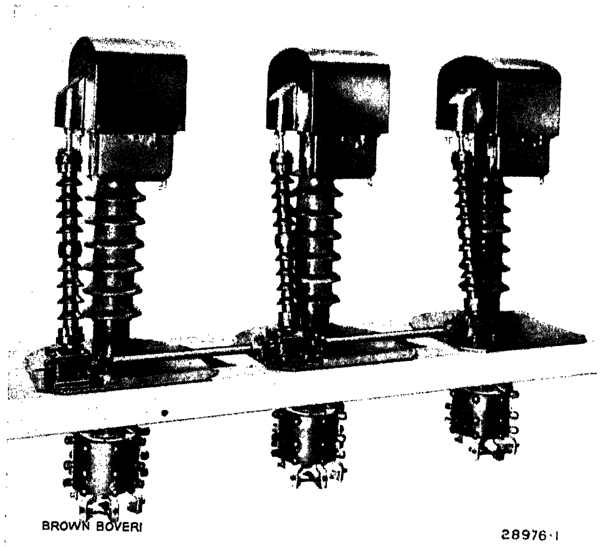


Fig. 13. — Three-pole on-load tap-changing switch Type HF 16 i for outdoor erection. Rated voltage 64,000 V, rated current 400 A, number of steps ± 6.

contact spacing. The voltage has increased or decreased by the amount corresponding to one step.

In order that the switching operations of the selector should take place under no current, that is without sparking, the current circuit of each brush is broken before the said brush leaves the contact. This is the duty of the sparking switch. The latter is built on to the bushing and is, therefore, outside the transformer proper. In this way, the sparks produced by the sparking switch have no influence on the properties of the oil, and, thus, no influence on the life of the transformer.

The regulation of the voltage under load calls, further, for the passage from one contact to the

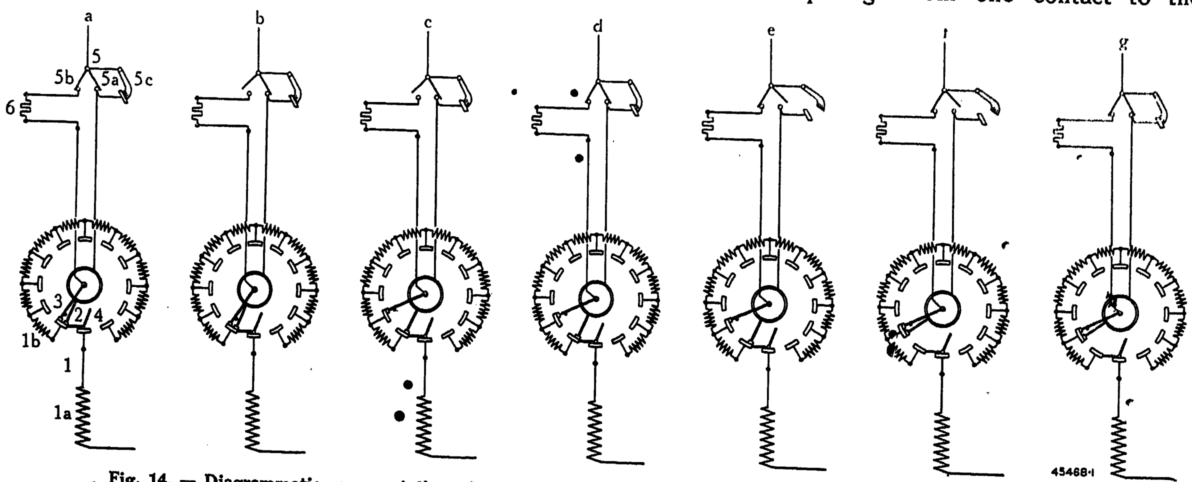


Fig. 14. — Diagrammatic representation of the operating method of an on-load tap-changing switch Type H.

1. Transformer { 1a. Main winding. 1b. Regulating winding.
2. Main brush.
3. Auxiliary brush.
4. Change-over knife.
5. Sparking switch { 5a. Main switch. 5b. Auxiliary switch. 5c. Brush element.
6. Step resistance.

next without interruption. Therefore, it is impossible to prevent the selector momentarily touching two neighbouring winding taps at the same time and, thus, bridging a voltage step. This bridging must not assume the character of a short circuit and it is, therefore, necessary to limit the strength of the current by a resistance, termed the bridging resistance.

Fig. 14 illustrates the important phases which are passed through when the selector passes from one step to the next. The switching process corresponds to a complete revolution of the driving shaft.

There are cam discs mounted on the driving shaft which control the sparking switch of the on-load tap-changing switch. Thus, the selector and the sparking switch are driven by the same shaft, so that the correct switching procedure of the various elements (double brush and sparking switch) forcibly take place in correct sequence, for both senses of displacement. Up to voltages of 24,000 V and current strengths up to 250 A, the sparking switches operate in air and for higher voltages and currents they operate oil-immersed. Both designs allow of easy supervision of the sparking contacts, by easy accessibility, thereto. Tests have shown that the sparking contacts only require to be replaced after about 50,000—100,000 switchings (the smaller figure being for on-load tap-changing switches for rated currents of over 250 A), and this assuming that the switchings take place under full load.

Table III contains a list of the single-pole, on-load, tap-changing switches Type H, for indoor, and Type HF, for outdoor erections.

TABLE III.

Rated voltage	Rated current A	Number of steps max.	Test voltage V
Types H and HF			
24,000	250	10	64,000
37,000	250/400/640/1000	10	86,000
37,000	1600	4	86,000
50,000	400	6	119,000
64,000	400	6	152,000
87,000	400	6	196,000
Type HF			
110,000	400	6	240,000
135,000	400	6	320,000
150,000	400	6	350,000
187,000	400	6	430,000
220,000	400	6	460,000

The highest admissible regulating range of the on-load, tap-changing switch Types H and HF is about 20 % of the rated voltage. With complete utilization of the number of taps on the selector, the step voltage is, thus, limited to about 2 % of the rated voltage, when ten steps are provided and to about 3 % of the rated voltage when six steps are provided.

The design of the on-load tap-changing switch Types H and HF allows of doubling the regulator range, with the help of a single change-over switch (Figs. 13 and 14). With the change-over switch the beginning and end of the regulating winding are changed over, so that the said regulating winding can be, not only added, but substracted from the main winding of the transformer. A special advantage of this solution is the doubling of the number of steps without having to increase the number of taps on the transformer winding.

(b) *Tap-changing switch inserted at the neutral point, Types LS and LSF.* — The existing series of the on-load tap-changing switches inserted on the phase, Types H and HF, has been increased, recently, by a series of neutral point on-load tap-changing switches. This increase was rendered necessary by the greater demands made on on-load tap-changing switches. As, however, the H-type had given such an excellent account of itself, in every respect, the aim set for the new series of apparatus was, really, the creation of a switch which could be easily dismantled for freighting, took up little space and could be built as simply as possible for a various number of steps.

Table IV gives a summary of the new series.

TABLE IV.

Rated voltage V	Rated current A	Number of steps	Test voltage V
Type LS for indoor and Type LSF for outdoor use			
11,000	250	7/15/23/30	42,000
24,000	250/400/640	7/15/23/30	64,000
37,000	250/400/640	7/15/23/30	86,000
50,000	400/640	7/15/23/30	119,000
64,000	400/640	7/15/23/30	152,000
87,000	400	7/15/23/30	196,000
110,000	250	7/15/23/30	240,000
135,000	250	7/15/23/30	320,000
150,000	250	7/15/23/30	350,000

Both the design and the working method of these on-load tap-changing switches differ somewhat from those of Type H. For this reason, something must be said, here, on the subject.

As in the case of the on-load tap-changing switches Type H, the passage from one tap to the next is carried out by the selector. In order that this passage be without current flowing, the operation is prepared by the sparking switch, the load on the double brush of the selector being transmitted from one brush to the other, with a short bridging phase

through a resistance. The sparking switch is mounted on the bushing and is, thus, outside the transformer. Its switchings take place in air, or else in oil for high voltages and currents; the oil bath being quite separate from that in the transformer. Up till here, the method of operation is the same as for Type H.

The difference is in the design of the selector. Up to seven steps, the switch has a single selector, namely the so-termed fine selector, while for over seven steps there is a fine and also a coarse selector with one step or with several steps, according to requirements.

According to whether the on-load tap-changing switch is built without a coarse selector or with one, two or three coarse selectors, the number of steps tabulated below can be attained.

TABLE V.

Design of the on-load tap-changing switch	Number of steps of coarse selector	Number of steps of one phase	Winding:— Diagram of one phase	Number of taps on one phase
Without coarse selector . .	0	7		8
With coarse selector . . .	1	15		9
	2	23		10
	3	30		11

Fig. 15 shows a three-pole *fine selector* for 37 kV and 400 A. The eight contacts per pole are arranged in a circle. The double brush, driven by the shaft through a single tooth drive, establishes the connection between the contacts and the contact rings, that is to say, between the taps on the transformer winding and the sparking switch. As in the case of the tap-changing switch Type H, the sparking switch is also mounted on the insulator. The immobile connections between the contact rings and the sparking switch are carried through the insulator, so that the shaft only serves as the mechanical drive proper and plays no part in current transmission (in the case of switch H, the two concentrical shafts carry the current from the brushes to the sparking switch).

With the help of Fig. 16, showing the characteristic phases of the movement, it is easy to follow the switching process of the fine selector from one step to the next. The illustration only shows one pole of the fine selector.

Starting from the service position (phase a), first the circuit of one brush of the fine selector is broken by rotation of the shaft of the on-load tap-changing switch (phase b). This interruption transfers the load current to the second brush and the lower contact ring. The brush of the upper contact ring is now rotated forward without current (phase c). After this, the sparking switch closes the circuit through the bridging resistance (phase d) and then, immediately afterwards, interrupts the parallel circuit of the lagging brush (phase e). In this phase, the load current flows through the bridging resistance and does so until this resistance is shunted by the sparking switch (phase f). The lagging brush is now rotated forward under no current (phase g). Finally the sparking switch closes the circuit of this brush so that in service position (phase h) both brushes are in parallel and both carry the load current. The whole process corresponds to one complete revolution of the driving shaft of the on-load tap-changing switch.

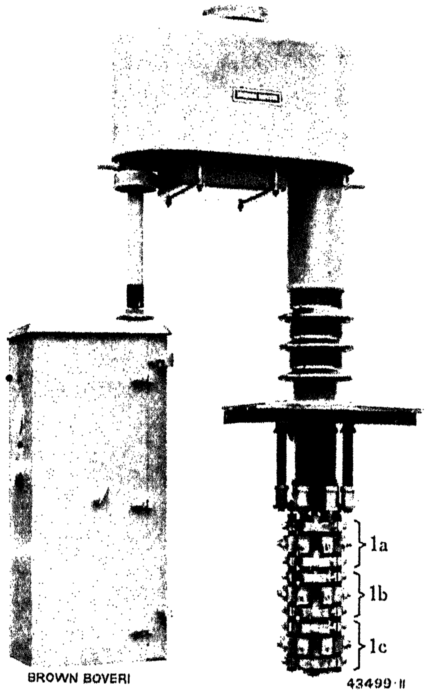


Fig. 15. — **Three-pole on-load tap-changing switch, Type LSF 37 i for outdoor erection. Rated voltage 37,000 V, rated current 400 A, fine selector for four steps.**

1a, 1b, 1c: the three-phases of the fine selector.

As already mentioned, the control of the two brushes is carried out by single-tooth drive. They are displaced in relation to one another and, thus, produce the alternative movement of the two brushes. The movement of the sparking switch is dictated by cam discs mounted on an auxiliary spindle directly-coupled to the main shaft of the on-load tap-changing switch.

As the latter is inserted at the neutral point of the winding, there are, relatively, small differences of voltage between the contacts of the three phases, and this permits of a three-phase design. The three single-pole elements are mounted directly one above the other, in the way shown in Fig. 15.

As was said, before, the on-load tap-changing switch can be built for bigger numbers of steps by adding a *coarse selector*. The design of the coarse selector is similar to that of the fine selector in as far as the arrangement of the contacts goes. Cor-

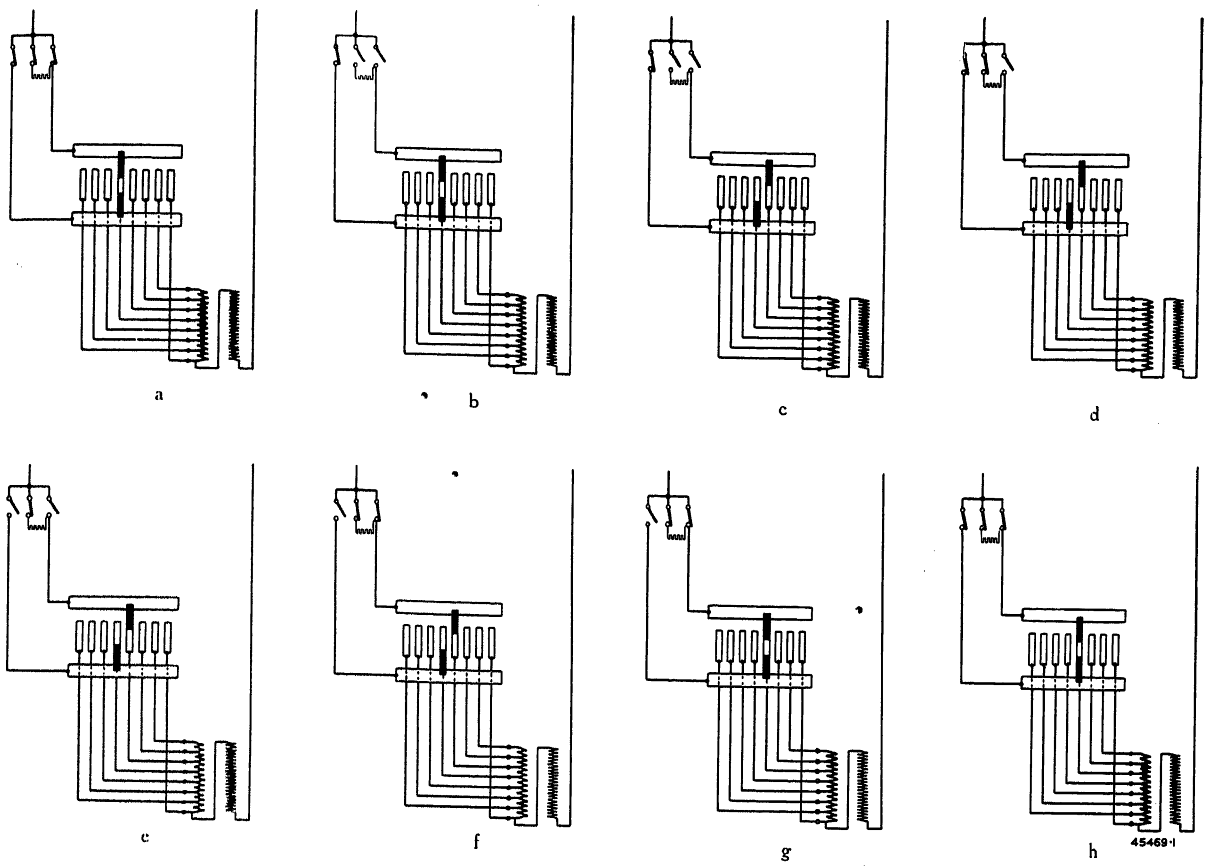


Fig. 16. Diagrammatic representation of the working process of the fine selector, Type L.

responding to the smaller number of steps, the design of the current collector is simplified. It is true that the design has two brushes, as well, but the latter encompass a fixed angle and cannot move relatively to one another.

Fig. 17 shows the most important phases of the switching process when the coarse selector moves over to the next coarse step.

Starting from the original position of the on-load tap-changing switch in which the whole regulating winding is cut out and the main winding is connected to step 1, the fine selector rotates from position 1 to position 7. During this movement of the fine selector, the coarse selector does not move; it remains on the first step. The service position in which there are six steps of the regulating winding in series with the main winding corresponds to phase a. If the switch shaft is further rotated the phases b—h are passed through during one complete revolution of the said shaft, so that in service position 8 (phase h) a further step (the seventh and last) of the regulating winding has been connected up. Towards the end of this movement (phase g), the double brush of the coarse selector rotates by an amount sufficient to allow the leading brush to touch the contact of the second coarse step. The brush carries no current because the upper contact ring of the coarse selector is connected to a contact of the fine selector which has not yet been touched by the double brush of the fine selector. The second current-carrying brush of the coarse selector remains in contact with the contact of the first coarse step during the said movement so that there is no interruption of current. Following service position 8, a further revolution of the driving shaft produces the phases i—p of the switching process. To begin with the current of the upper brush of the fine selector is interrupted by the sparking switch and the said brush is rotated on to the next step (phases i and k). After this, the sparking switch closes the circuit of the upper brush of the fine selector again and thus connects the upper brush of the coarse selector, that is the second step of the coarse selector, to the system. For the time being, the bridging resistance is inserted (phase 1) but after the sparking switch has broken the connection between the lower brushes of the fine and coarse selectors and the system (phase m), the bridging resistance can be short-circuited by the sparking switch (phase n). The lower brushes of the coarse and fine selectors rotate further, that of the coarse selector runs on to the contact under no current and that of the fine selector finds itself at the end of the movement together with the upper brush on

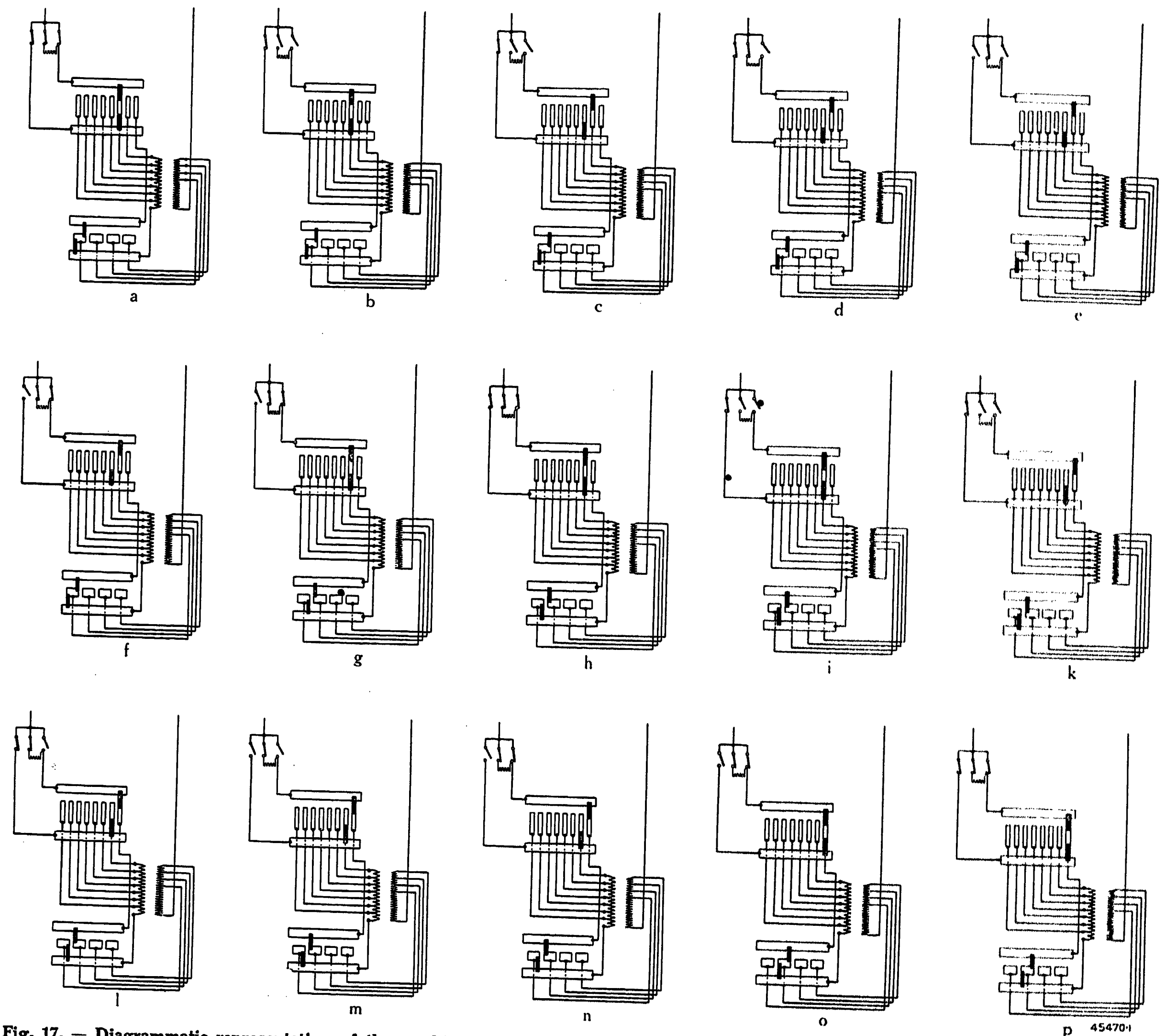


Fig. 17. — Diagrammatic representation of the working process of the on-load tap-changing switch, Type L (coarse selector and fine selector) in the passage to the next coarse step.

contact 1 (phase o). Finally, by the closing of the sparking switch, the current of the lower brush of the fine selector is closed again (phase p). In this service position (position 9) the main winding is connected to step 2, the regulating winding is cut out and, reckoning from the initiation of the regulation, the eighth tap of the transformer is in service.

The step voltage of the coarse selector is $^1/_7$ bigger than the voltage range of the sum of the seven steps of the fine selector; it, therefore, corresponds to eight voltage steps. This stepping allows of uniform regulation over the whole range and this so that for every complete rotation of the driving shaft of the on-load tap-changing switch, the voltage is regulated by one step, without there being dead positions on the switch.

From a constructive point of view, the fine and the coarse selectors can be pleasingly combined in a compact, vertical design. Fig. 18 shows Type LSF 64k for 64 kV and 640 A. The coarse selector (2a—2c) is placed at the bottom of the fine selector (1a—1c). The two selectors are suspended to the cover of the transformers as separate inferior part of the on-load tap-changing switch. Insulating tubes play the part of fixing bolts. The upper part of the tap-changing switch composed of the insulator with the built-on three-pole sparking switch (3) and the three-pole resistance (4) can be inserted into the lower part like a plug into its socket. After the upper part has been plugged in, there are no other connections to be made.

The following features of this neutral-point switch should be mentioned: —

The open vertical design requires a minimum of space and causes a minimum of obstruction to the circulation of the oil in the transformer.

The contacts are designed as rolling contacts and the bearings as ball bearings. This not only re-

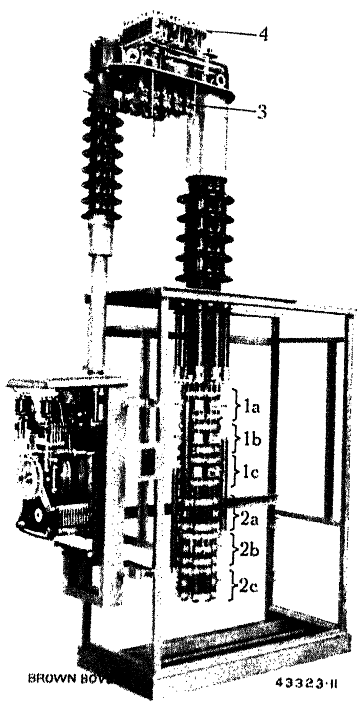


Fig. 18. Three-pole on-load tap-changing switch, LSF 64 k, for outdoor erection. Rated voltage 64,000 V, rated current 640 A with fine selector and coarse selector.

1a, 1b, 1c: the three phases of the fine selector.

2a, 2b, 2c: the three phases of the coarse selector.

duces the torques but keeps them, practically, constant in service so that the greatest possible guarantee of perfect switching service is attained.

If it is considered necessary to despatch the transformer without its terminals, on account of freighting conditions, the bushing insulator with built-on on-load tap-changing switch can be dismantled without loosening the connections between the selectors and the regulating winding and can be mounted again, on site.

The transition time from one step to the next is about two seconds. The bridging resistances are only inserted for a fraction of this time (about 0·2 s) so that they have small dimensions and can be combined to form a whole with the on-load tap-changing switch. Despite their restricted dimensioning these resistances are amply dimensioned for the work they have to do and so can stand up to continuous operation of the switch.

(c) *Drive of the on-load tap-changing switch.*—Power storage (spring-operated) drives are used, practically, exclusively. As compared to drive by motor, it has the advantage of the completely mechanical drive so that the switching process is not dependent on the reliability of an auxiliary source of electric power. It is true that a small electric motor is needed to store the requisite power, but it plays no part in the switching process. If, for some reason, the motor should stop owing to the failure of its power supply, before it has wound up the spring to the end position, no switching operation of the on-load tap-changing switch takes place.

The utilization of power-storage (spring-operated) drive does not, of course, exclude the danger of the switch being immobilized as a result of a mechanical defect. However, a flywheel combined with an ample power reserve of the spring has been provided so that break downs of this kind are, practically eliminated. If against all probabilities, the switch should get immobilized, a signalling device informs the service operators of the fact. Automatic cutting out of the transformer ensues in the case of the on-load tap-changing switch being immobilized with bridging resistances switched in. Thus, damage to material resulting in a long interruption of service is prevented,

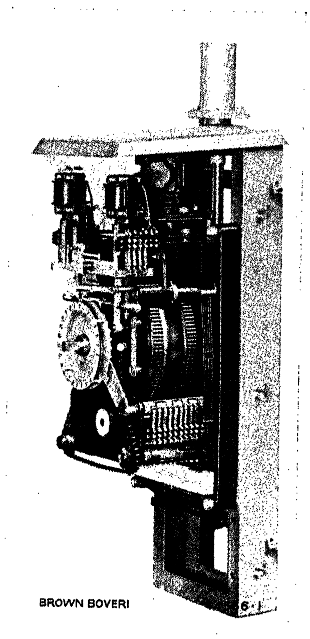


Fig. 19. — Power storage (spring-operated) drive Type R_2, for an on-load tap-changing switch. Shield removed.

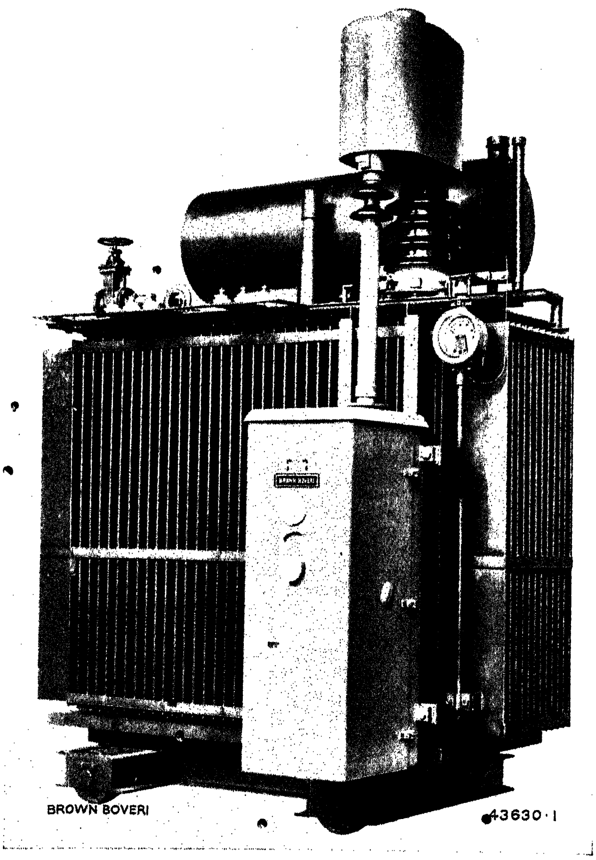


Fig. 20. — Three-phase regulating transformer 1000 kVA, for outdoor erection with built-in, neutral-point, on-load tap-changing switch, Type LSF 11 h and power-storage (spring-operated) drive, Type RF 2.

with certainty. The on-load tap-changing switches Types LS and LSF are now only built with power-storage drive. The chief data on these drives is given in Table VI.

TABLE VI.

Different designs possible			
For indoor erection	Type R 2	With hand or with motor winding up of the power-storage spring	Motor for D.C. or for A.C. output about 300 watts
For outdoor erection	Type RF 2		
Switching period (switching process of on-load tap-changing switch, winding up of spring included) about 15 s; on special request about 5 s.			

By putting on a handle, the switch can be operated, in an emergency, by hand. Fig. 19 shows how the power-storage (spring-operated) drive is designed. At the top, in the middle, the driving motor is seen which transmits its power to the geared rim combined to the ends of the spring, this through gear wheels and worm drive. In front of the motor are placed the two switching coils for left or right running of the motor according to the two regulating directions of the on-load tap-changing switch. There are sufficient contacts for auxiliary purposes (signalling and interlocking). To mark the position of the switch, a number disc is also added.

Fig. 20 shows a 1000-kVA regulating transformer with built-in on-load tap-changing switch on the neutral point and power-storage drive.

The development of the new series of on-load tap-changing switches has allowed of adapting still better the regulating transformers to the current and voltage conditions met with in practice. The thoroughly developed design of the neutral-point on-load tap-changing switch is a guarantee of reliable service.

(MS 551) *A. van Gastel. (Mo.)*

TURBO-ELECTRIC POWER-GENERATING PLANT ON A FLOATING DREDGER USED FOR THE DREDGING OF TIN.

Decimal index 621. 34 : 621.879. 3.

A steam turbine plant, of a kind which is not met with every day, was delivered at the beginning of 1936, by Brown Boveri, to the Larut Tin Fields Ltd., in Taiping (Federated Malay States) for use on their tin dredger No. 4 (Fig. 1).

On the occasion of the electrification of the said dredger, the Anglo Oriental (Malaya) Ltd., who are general managers of the above-mentioned undertaking, chose a three-phase turbo-generator plant of 500 kW output to generate the electric power required. Originally, this dredger was equipped for steam drive, exclusively. In order to increase its performance, transformation to electric drive had been agreed on, whereby the boiler already installed, which is a water-tube unit with travelling stoker by Babcock and Wilcox, had to be retained. For this reason, the installation of a turbo-electric set was decided on. To our knowledge, this is the first time one has been mounted on a tin dredger.

The tin found in Malaya is, usually, under the form of an alluvial ore (tinstone, "cassiterite", $Sn\ O_2$) in the form of heavy, black sand mixed with big quantities of lighter sand, gravel and clay, etc. The only economical way of separating the heavy tin ore from the lighter material is by washing out in water, a process which carries off the lighter portion and leaves the heavy ore. After a second and thorough washing, the latter is dried and then carried to smelting plants. In Malaya, there are big deposits of tin ore to be found in swampy regions and also in regions where water is very prevalent. Dredging is the most advantageous method of getting out the tin, this by means of bucket dredgers. Although these dredgers are expensive as to first costs, they allow of handling big quantities of material at relatively low working costs, this independently of the influence of the prevailing weather and without danger of infiltration of water into the working of the plant. Working as an independent unit, a dredger like this operates in a pond dug out by itself in the soil holding tin ore, the dredger continuously washing out the ore and throwing behind it the useless sand and stones which fall to the bottom again.

Generally speaking, a tin dredger is composed of:—

a) the floating pontoon,
b) the dredging gear proper with winding gears to move the different parts,
c) the equipment for treating and extracting the tin ore,
d) the central power-generating plant for the various drives.

It would be beyond the scope of this article to give a detailed description of all the various devices as well as of the power plant.

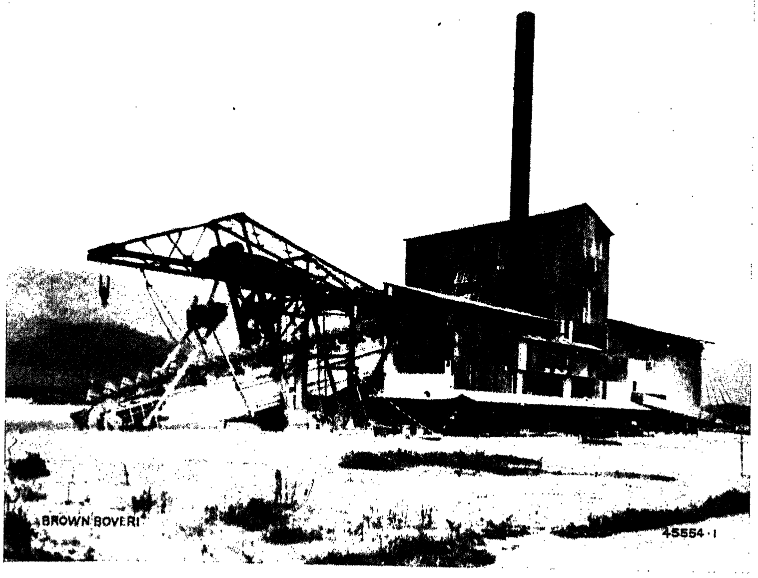


Fig. 1. Floating dredger No. 4 for tin dredging belonging to the Larut Tin Fields Ltd., Taiping (Federated Malay States).

When this dredger was made over from steam to electric drive, a 500-kW Brown Boveri steam turbo-set was put in, this being the first turbo-electric power plant to be put on a tin dredger.

In this respect the reader is referred to the technical literature already published on the subject.[1] As regards the methods of treatment, it need only be said in order to grasp the stage of development reached to-day that of the two treating and concentrating processes in use, namely the washing-out process in a series of parallel washing gutters (Palong method) and the settling process with special boxes and pulsating water contents (Jig method), the latter would seem to be the one most favoured, to-day.

All the gears just mentioned are mounted on a floating, rectangular pontoon which is anchored to the banks of the dredger pond by means of five steel cables, one at each angle and the fifth (head line) passing from the centre of the pontoon towards the working front. The fifth cable determines the depth of the cut dredged in the face and remains unchanged during a whole cut. By means of the four other cables and of a mooring winch which coordinates the action of the four anchoring cables, the dredger is displaced sideways, to and fro, along the working face, during which it passes through an arc of a big circle of which the taunt head line is the radius. After each sideways pass, the bucket ladder is sunk lower, by a determined amount, through the agency of a ladder hoist, until, finally, it attains the deepest position. Then it is entirely raised, the head line is taken in by the thickness of one cut and another dredging operation is initiated, in the way described.

Formerly, steam, in conjunction with reciprocating engines, was used, solely, as driving force on the dredger. Recently, however, individual electric drive of the various gears has taken the place of steam drive, because of its many advantages (saving of space, easier supervision, economy, lower upkeep costs, reliability in service and, as a result, a greater number of working hours). Of those dredgers which have been entirely electrified and have their own central power stations only those with Diesel-electric power stations have been known, up till now. Generally the power station of these dredgers consists of three Diesel generator sets of which two serve as service units and the third as a stand-by unit.

In the case of the Larut dredger, No. 4, with its turbo-electric power plant, there is, however, only one turbo generator set (Figs. 2 and 3). The fully recognized reliability of steam turbines, allows of doing without a stand-by unit. Further, in putting in a steam turbine with the balanced, smooth running of the masses in movement, it was not found necessary to strengthen the structure of the pontoon. For this reason and because the boiler plant was already installed, as said before, these clients decided on in-

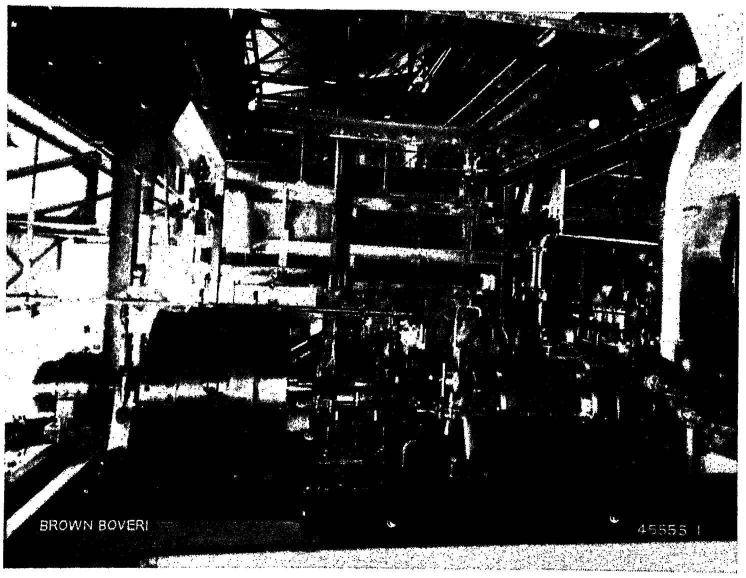


Fig. 2. — 500-kW three-phase turbo-set on the tin dredger No. 4 of the Larut Tin Fields Ltd., Taiping (Federated Malay States).

[1] For example see Raute: — "Zinngewinnung durch Baggerarbeit," Z. VDI year 1932, page 746.

stalling a Brown Boveri turbo-generator set. This meant a considerable saving in space, as compared to the former reciprocating engines.

As is usual with turbo sets of the power range in question here, the turbine and the generator it

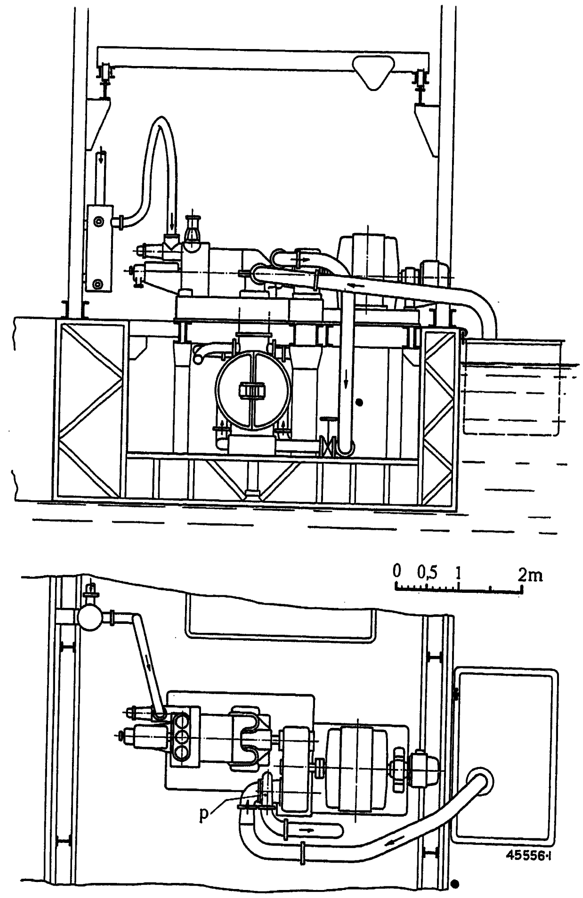


Fig. 3. — Erection layout of the 500-kW three-phase turbo-set on tin dredger No. 4.

The turbo-set is placed crosswise to the longitudinal axis of the pontoon. The circulating pump (p) is directly built-on to the set. The condenser is in two parts (allowing of cleaning without interrupting service). A steam ejector is used for the extraction of air from the condenser.

drives run at different speeds; for steam economy reasons the turbine runs at the relatively high speed of 5500 r. p. m. while the generator, in order to keep cost down, runs at 1000 r. p. m., a speed at which the expensive turbo design is not necessary. There is, therefore, a reduction gear placed between the two units, a welded bedplate combining all the parts of the set.

The steam conditions worked to are:—
11·55 kg/cm² abs, 232° C, the cooling-water temperature is 28° C. The generator output is 500 kW maximum, 50 Hz, 400 V, p. f. = 0·8.

The design takes into account that running in an inclined position must be reckoned with, in other words the conditions are rather similar to those in marine drives. As regards auxiliaries, the principle of the independent Brown Boveri "Turbloc" has been applied as far as is possible; thus, the circulating pump is direct-driven from the main gear so that cooling water circulates from the very first rotation of the turbine. The condensate pump is direct-coupled to the main generator through electric transmission. Thus, the turbo generator set can be started up independently of any other source of current or power.

On account of there being no stand-by set, special measures were necessary in order to assure continuous running despite the fact that the cooling water available is very muddy. The surface condenser is of the two-part design, an original Brown Boveri type of condenser, which has since been imitated by many firms, and which allows of cleaning one half, the other remaining in service. The cooling tubes are expanded into the condenser-shell end plates at both ends and are given a wavy-shape so that they can expand and contract freely under temperature differences, this is standard Brown Boveri practice. There is a special sieve chest for the cooling water intake; it is suspended on one side of the floating pontoon and it can be moved about. In this way the cooling-water pump takes in relatively clean water. A steam ejector of Brown Boveri design looks after the air exhausting of the condenser.

The standard apparatus and service instruments are mounted on a switchboard panel. It should be noted that voltage regulation is taken care of by a Brown Boveri automatic quick-acting regulator, which, as experience has shown, maintains, practically, constant voltage despite the sudden and, often, very violent load surges occurring. Thus, an electric-power generating plant has been built with properties of stability which would, otherwise, only be found in big central power stations.

The plant has, now, been in service for more than one year and has given every satisfaction.

To conclude, it should be said that the dredger is equipped with buckets of 255 litres capacity (9 cb. ft.), which work at the rate of 20 buckets per minute. With 600 working hours per month, this means an output of 183,600 m³/month (240,000 cb. yards); the load on the turbo-set being 350 kW under these conditions.

(MS 571) *E. Klingelfuss. (Mo.)*

EVAPORATOR PLANTS.

Decimal index 621. 187. 123.

THIS article is limited to a description of evaporator plants and the process they work to for the production of make-up water for use in thermal-electric power stations. A plant of this kind is composed of the evaporator proper and of the condenser. The quantity of water to be evaporated is relatively small as compared to the total quantity of feed-water in circulation.

The high temperatures and pressures worked to in modern boilers, as well as the design of the latter, require and, in fact, make essential, the use of very pure feed-water. Brown Boveri's experience and views on this subject have been clearly defined in numerous articles which have appeared in a variety of technical publications, in the course of recent years. The importance to be attached to feed-water supply for the modern boilers and the part played by the treatment of the make-up water in a modern plant is made very clear in the publications in question.

According to its source of supply, the raw water contains in suspension organic and inorganic impurities, as well as salts, acids and gases in solution. On account of their mechanical action and chemical influences on the boiler, these different ingredients are, often, the cause of serious and, sometimes, of irrepairable damage. The said ingredients consist chiefly of air in solution with free carbonic acid and of salts of calcium, magnesium and sodium, that is of carbonates, sulphates, chlorides, nitrates, and silicates. The corresponding free acids as well as other combinations may also be encountered. The amount and composition of the impurities differ greatly and depend, chiefly, on the source of the water supply. Useful information on what measures should be adopted in order to obtain satisfactory make-up water can only be supplied by a complete analysis carried out before the evaporator plant is built.

The gases in solution in the water have to be eliminated before the water is introduced to the boiler. The de-aerators built by Brown Boveri, their action and insertion on the feed-water circuit, will be explained in subsequent paragraphs. Fig. 1 shows how many kilogrammes of one of the most common gases can be contained in solution in one cubic metre of water under a pressure of 760 mm mercury column and at a determined temperature. Oxygen and carbonic acid are particularly dangerous.

The evaporator plants put forward by Brown Boveri are exclusively composed of heat-exchanging apparatus. The necessary heat to evaporate the raw water is taken from steam extracted at suitable points on the main turbine and at the lowest pressure possible, so that, as live steam, it may have first done as much work in the turbine as possible. Usually, the evaporator plant is combined with one to heat up the feed water. The condenser part of the evaporating plant then simply acts as a feed-water heater. The number of feed-water heating stages varies according to the size of the turbine and service conditions. Each stage of the feed-water heater is connected to a corresponding steam-extraction point on the main turbine. Fig. 2 shows the general layout of a plant of this kind. The evaporator is inserted between two feed-water heater stages. The raw water is led to the evaporator through pipe 6, the vapours produced are condensed in the feed-water heater F_2. The amount of heat freed by this condensation is, thus, utilized to heat the feed water of the boiler and is not lost. The evaporator is shown in Figs. 3, 5 and 6. It works on the principle of a surface heat exchanger with immersed heating surface C (Fig. 3) formed of a nest of copper tubes. A float regulator 4 maintains the raw-water level constant in the big vapour chamber A, so that the nest of tubes C is immersed. The heating steam extracted from the

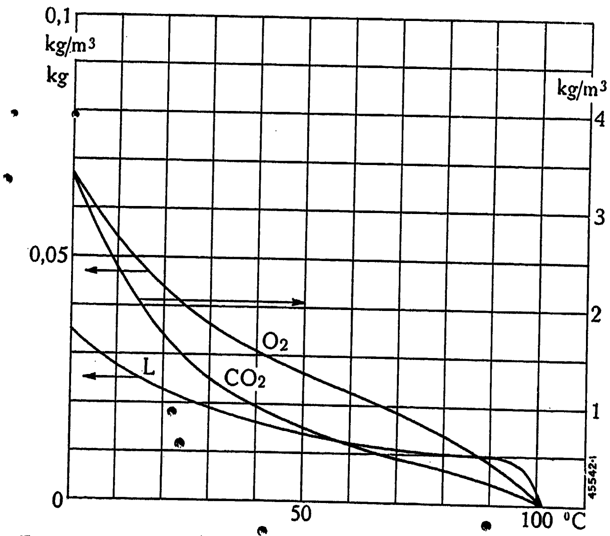


Fig. 1. — Solubility of gases in water in function of the temperature, at a total pressure of 760 mm of mercury.

Total pressure = Partial pressure of gas + saturation pressure of water.

O_2 = Oxygen. L = Air. CO_2 = Carbonic acid.

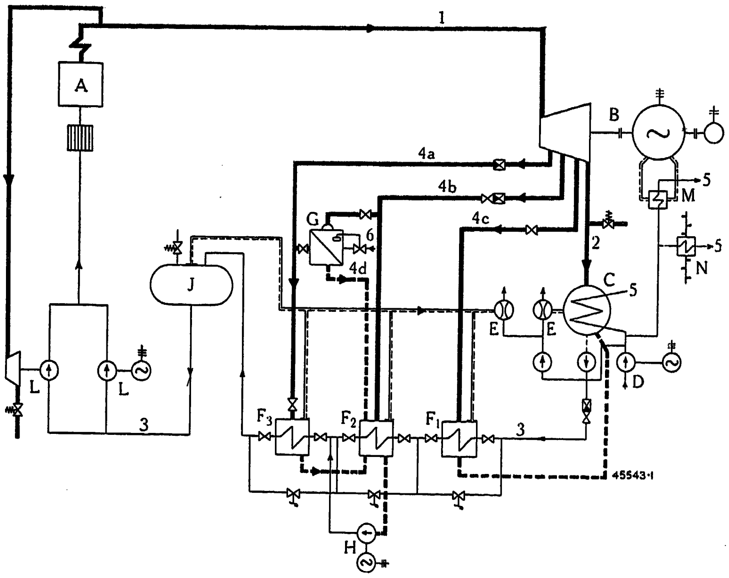


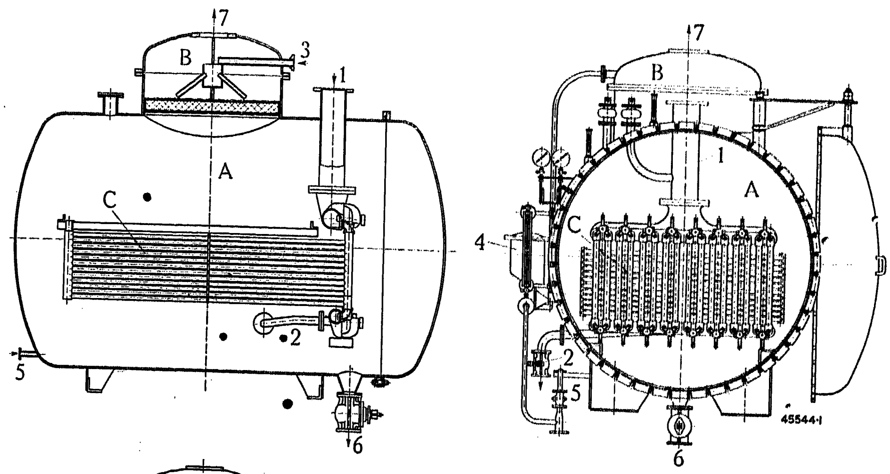
Fig. 2. — Heat diagram of a standard plant with three-stage feed-water heating and make-up water treatment by distillation.

A. Boiler.
B. Turbo-set.
C. Condenser.
D. Condensation pump set.
E. Air ejector.
F 1—3. Feed water heaters.
G. Evaporator.
H. Feed-water heater condensation plant.
J. Deaerator and feed-water tank.
L. Feed-water pump.
M. Air cooler.
N. Oil cooler.

——— = Water.
- - - - = Air.
= Oil.
▬▬▬ = Steam.
▬ ▬ ▬ = Condensate.

main turbine is led into the nest of heating-tubes C through pipe 1, the steam condenses here surrendering its heat to the raw water being vaporized and then being carried away as condensate through pipe 2. The stack of tubes is composed of 6 to 14 grid-shaped elements (banks), according to the size of the evaporator; these elements are composed of a number of horizontal copper tube lengths which are soldered at both ends into two vertical head pieces. The distribution of the tube banks and the spacing of the horizontal tubes are so made that scale can easily be removed. On the front end, the tube banks (a) (Fig. 4) are connected, above, to the hot steam distributor and, below, to the condensate collector (c). Securing in position is made by clamping pieces (d), bolts (f) and nuts (e), which is clearly shown. Each couple of banks is held by one clamping piece. At the back end, the tube banks are carried by clamping pieces on an angle-iron rail on which they can slide forward when being dismantled. Thus, the whole design is very simple and rugged in construction. Fig. 6 shows how easy it is to withdraw the tube banks. The nest of pipes is subdivided into such a big number of banks that one to two men suffice to take out or put in a bank without special lifting gear. The dimensions of the fixation bolts is such that they are easily loosened even when there is a heavy layer of boiler scale on the tubes, as may happen at the end of a long period of service.

The dimensions of the evaporator shell are ample and the surface of evapor-



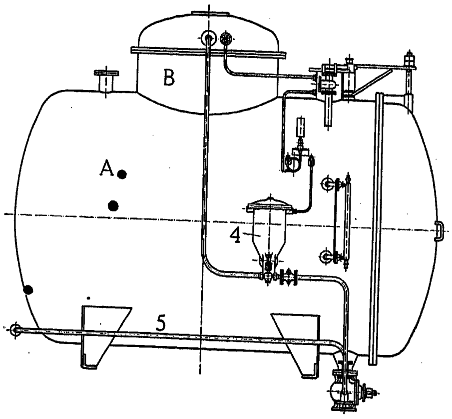


Fig. 3. — Diagram of evaporator.

A. Vapour chamber.
B. Vapour collector.
C. Heating surface.

1. Inlet for hot steam.
2. Outlet for hot condensate.
3. Inlet for raw water.
4. Float regulation.
5. Swilling pipe.
6. Blow-down outlet.
7. Vapour outlet.

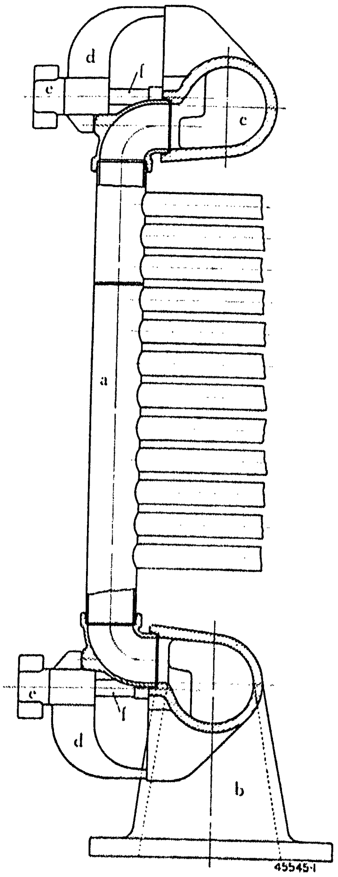


Fig. 4. Method of securing a heating element to permit of its being easily taken out.

a. Grid-shaped heating element (bank).
b. Steam distributor.
c. Condensate collector.
d. Clamping piece.
e. Wing nut.
f. Bolt.

ation is quite sufficient. The said surface has to be big enough to prevent the vapour which is being drawn off from forming waves on the surface of the water and thus causing water to be carried off with the vapour. The evaporating surface determines the size of the vapour chamber and, therefore, of the evaporator. The vapours from the raw water collect in dome B (Fig. 3) and are led from here to the feed-water heater through duct 7. There is a spray system in the lower part of the dome, through which the vapours rise while the raw water led in through pipe 3 falls in counter flow. This spray system fulfills two objects:— on the one hand, the foam and the solid particles which may have been carried along with the vapour are washed (held back) and, on the other hand, the raw water flowing downwards at low speed is warmed. By the warming of the raw water in the evaporator a part of the magnesium and calcium salts in solution in the water are eliminated. These salts collect as a sludge at the bottom of the evaporator and are blown down through pipe 6 during cleaning. The blow-down operation can be assisted by a water jet. This is produced by opening the valve in pipe 5, the jet then scavenging the bottom of the evaporator.

The thermometers, pressure gauges, water-level indicators and safety devices required for supervision are mounted so as to be easily read. The evaporator is closed, in front, by a cover held in position by hinge bolts which can be quickly loosened. The cover is on a suspension device (Fig. 6) round which it can rotate, thus no special gear is required to open the evaporator. Figs. 5 and 6 show the evaporator closed and open. Fig. 6 shows, clearly, how easily the heating surfaces can be withdrawn for cleaning. Thanks to the subdivision of the heating surface into a number of banks, each of these can be taken out independently by unskilled operators and can be scraped clean, all round.

Fig. 7 shows the essential design of the feed-water heater F_2 (see Fig. 2) in which the vapours from the evaporator G are condensed. The boiler feed water which flows through the inside of the cooling tubes of the nest in several passes serves

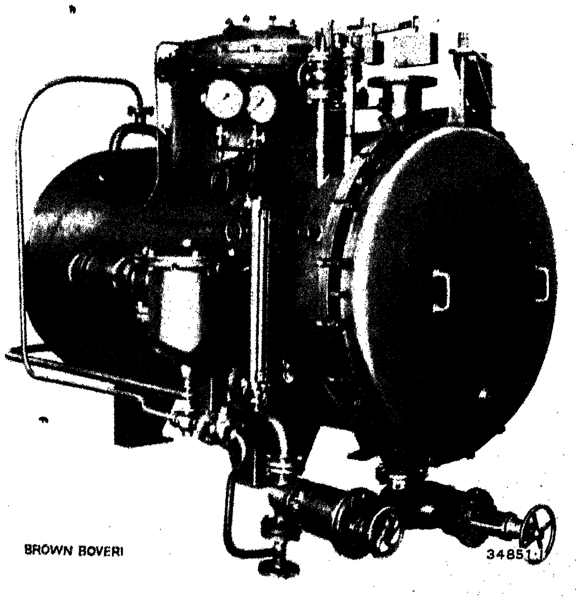


Fig. 5. — Evaporator.

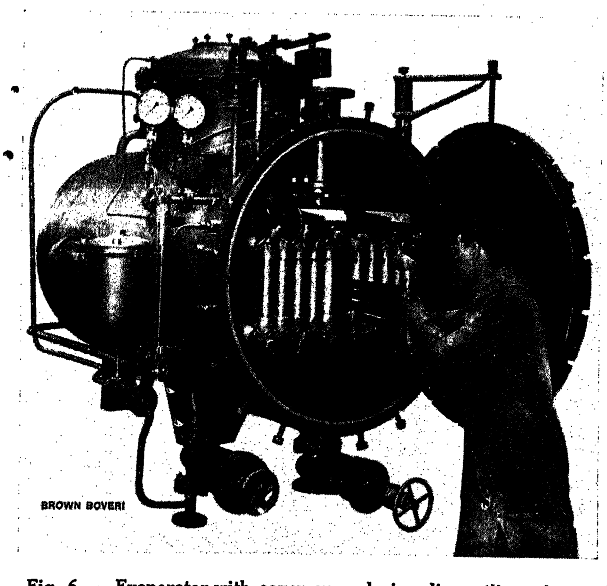


Fig. 6. — Evaporator with cover open during dismantling of one of the heating elements.

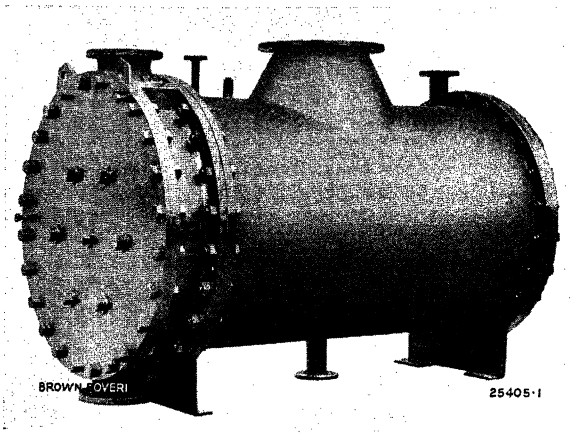


Fig. 7. — Feed-water heater.

as a cooling agency. The tubes are given a slight set to take up expansion due to differences of temperature; they are expanded into the tube plates at both ends. This is the only way of making the joints of the tube nest absolutely tight. No deposit is formed on the feed-water heater surface which is only in contact with clean steam and condensate; thus, there is no necessity of dismantling the said heater.

Each feed-water heater has also got its deaerating pipe through which it is either connected to the condenser or to an auxiliary ejector apparatus. This allows of completely degassing the condensate in the feed-water heater which former can then be fed to the boiler. Obviously, the degassed feed water must be prevented from coming into contact with air or gases again before being supplied to the boiler. For this reason, Brown Boveri uses totally-enclosed feed-water tanks (surge tanks) which are either connected to the condenser or to an auxiliary ejector (see Fig. 2, Pos. J). According to Dalton's law, the sum of the partial pressures for any mixture of gases above a liquid is equal to the total pressure. The quantity of gas in solution in the water is proportional to the partial pressure of the gas over the water. The boiling point of the water depends on the total pressure above the water. If the gas and vapour mixture is exhausted from a totally-enclosed tank in which there is boiling water and the said gas-vapour mixture over it, then the partial pressure of the gases will gradually fall and that of the steam rise because the quantity of gas present in the tank is limited. The partial pressure of the steam about the fluid thus rises until that total pressure is attained which corresponds to the boiling point of the water. At 100° C the pressure is 760 mm Hg at 30°, on the contrary, it is only 33 mm Hg.

The feed-water surge tank must be placed about 10 m above the axis of the feed-water pump so that no vacuum can be created in the suction pipe. This might occur if, for example, a very low temperature was caused inside the tank, that is a very low pressure, at periods of interruption of service.

By this method of degassing, the air and gases are drawn off and the same is, also, done in every feed-water heater.

However, there is another system which keeps the water, from which gas has been eliminated, constantly under pressure and, thus, prevents it getting saturated with gas again. In this case, a layer, or cushion, of steam must be provided over the surface of the water in the surge tank, which calls for suitable regulating organs, either thermostats, pressure regulators or steam reducing valves. All these accessories, however, are liable to fail and, for this reason, Brown Boveri gives preference to vacuum de-aerating in which air and gases are exhausted from the tank.

Further, it has been found that when the feed water is free of gases, it is not necessary to have such a high alcalinity as it was thought necessary to specify in recent years for modern boilers.

The condensate of the hot steam coming through pipe 4 d (Fig. 2) from evaporator G reaches the feed-water heater F_2, mixes with the condensate formed there and the whole is either pumped into the feed-water pipe by the pump H belonging to the feed-water heater, as shown, or else it flows straight back to the main condenser through a special pipe. According to the conditions and size of the plant, the one or the other solution is chosen.

In order to ascertain the amount of make-up water, that is to say the amount of raw water to be evaporated and for which the evaporator plant has to be dimensioned, the losses in the plant must first be ascertained and their cause. Losses to be mentioned here are:—

1. Losses on the steam side, through the glands and pipe vents, losses through leakages at flanges and valves, etc.
2. Losses on the water side, at the pump glands, in the drains and through leaky flanges, etc.
3. Blow-down losses proper of the boiler, as well as additional losses when starting up and closing down the machines.

In a modern thermal-electric power station the total of these losses should not exceed 1—3 % of

the rated steam production in so far as raw water is used for make-up. In industrial plants where the exhaust steam is used for heating purposes, these losses and the requisite amount of make-up water can attain 100%. In a case like this, the treatment of the water calls for quite other equipment than that described here. The above-mentioned losses 1 and 2 can be determined relatively simply and be reduced to an admissible figure without great difficulty. The losses under 3 are chiefly dependent on how the water is treated. The amount of blow down is chiefly determined by the salt concentration allowable and this varies from boiler to boiler and also depends on the characteristics of the feed water. These losses are very low when raw water is used for the make-up, as prepared in Brown Boveri evaporators. This make-up water contains considerably smaller quantities of salt than 12 mg/l, a figure which is generally considered allowable for the evaporated water. As a proof of the purity of the evaporated water from a Brown Boveri evaporator, it can be said here that, in a big power station in Belgium, part of the water is sold to apothecaries as distilled water. If, on the other hand, the make-up water is chemically treated the necessary blow-down is 30 to 50 and more times greater than in the case of make-up water from an evaporator. This is always assuming that no raw water can penetrate into the circuit of the feed water. For this reason, the tightness of the condenser has to be tested periodically. By expanding the condenser tubes into the tube-plates, Brown Boveri has, practically, eliminated leakages inside the condenser.

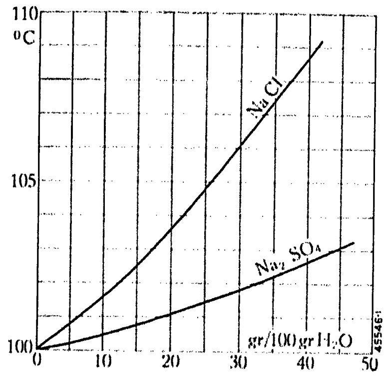


Fig. 8. Increase in boiling point of water by salts in solution.

N_aCl. Cooking salt.
$N_{a2}SO_4$. Sodium sulphate.

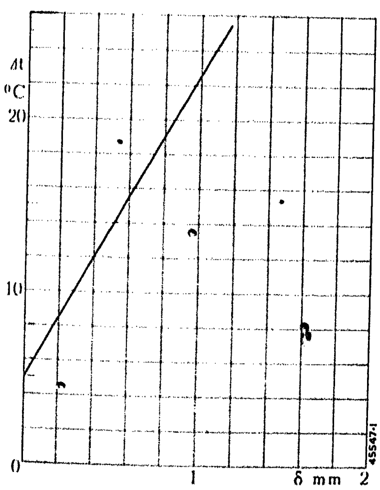


Fig. 9. — Influence of boiler scale on the difference of temperature required between heating tubes and vapour.

δ. Thickness of boiler-scale layer.
Δt. Difference in temperature.

Once the amount of make-up water has been determined, the dimensions of the plant can be fixed. Here, the admissible pressure difference and respective temperature difference between heating steam and evaporated vapour in the evaporator play a very important part.

The boiling temperature of a solution is higher than that of the pure water. The increase in boiling temperature depends on the salt concentration, as is shown in Fig. 8, which gives the rise in boiling point for some common solutions.

During service, the nest of hot tubes of the evaporator gets gradually covered by a layer of sludge and crystals from the impurities contained in the raw water. This coating is a poor heat conductor, its coefficient of heat conductivity being of the order of 1 kcal/mh °C. Fig. 9 shows the necessary difference in temperature in order to attain the passage of a given quantity of heat in function of the thickness of boiler scale on the tubes. Thus, Figs. 8 and 9 show the influence exercised by the concentration of salt solutions and by boiler scale on the necessary temperature between heating steam in the tubes and vapours in the evaporator. This shows that the

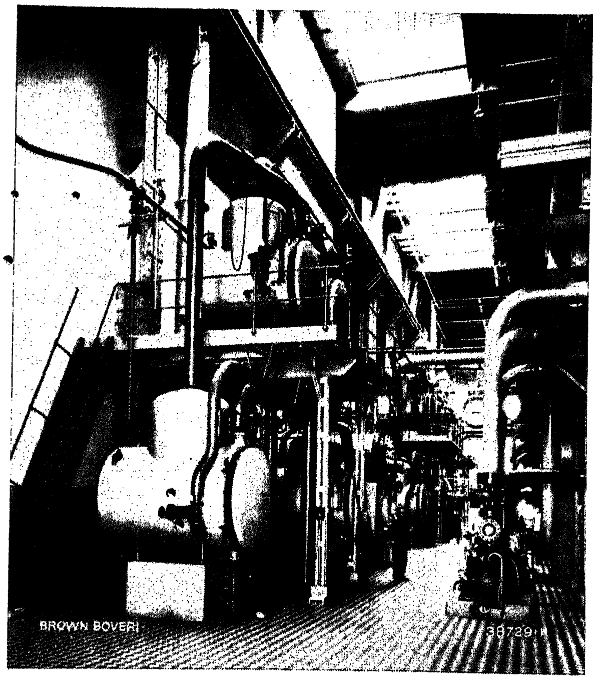


Fig. 10. — Evaporator plant of a big power station.

plant should not be dimensioned on the basis of too small temperature differences. Here, it should be remembered that the pressure of the heating steam at its extraction point on the turbine varies about proportionately with the load on the turbo-set. Care must, therefore, be taken that sufficient raw water can also be evaporated at partial loads. For this reason, the temperature at full load must not be too low.

The Brown Boveri evaporators are so amply dimensioned that, even when there are relatively heavy layers of boiler scale on the heating tubes, such as may be encountered in practice, they are still able to produce their rated quantity of vapour at a temperature difference of 20° C. A further advantage is that they can be supplied straight with raw water without requiring the latter to be first put through a preliminary chemical treatment. Further, feeding with sea water does not present any difficulty at all.

Fig. 10 shows an evaporator plant supplied by Brown Boveri to a big power station. The evaporators are located on two floors, one above the other, and one from the lower and one from the higher level are connected in series each two forming an evaporating set. The evaporator of the first stage is fed with live steam from the main turbine at 3·4 kg/cm² abs, at full load. The vapours from this first stage are used as heating steam for the upper evaporator, forming the second stage, while the vapours from the latter are condensed in a feed-water heater. The evaporator plant works to full heat recuperation. Each of the evaporators generates per hour about 3000 kg of vapour.

The conclusions of Brown Boveri's years of practical experience, in the boiler field and other steam plants are that evaporated and degassed make-up water is the best for boilers.

Since a number of years, Brown Boveri has been building evaporators and has evolved a design consisting of feed-water heater and evaporator with degassing device which is very suitable to modern thermal-electric power stations. The total output of the evaporators already built by Brown Boveri amounts to 280,000 kg/h of steam.

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THE FAULT-VOLTAGE TRIPPING OF SWITCHBOXES.

Decimal index 621.316.573 : 621.316.99.

THE fault-voltage tripping device is an organ which is built into the switchbox, in order to cut off the supply lead as soon as a voltage appears on any metal part accessible to touch (for example the motor housing) and which is strong enough to endanger human life or — in the case of agricultural plants — to endanger the life of animals; the said voltage being caused by a fault in the insulation or some other defect.

The method of operation is seen in the accompanying diagram (Fig. 1). The motor switch or supply-system switch 2 carries the fault-voltage tripping device, which is a small relay 3, the coil of which is connected, by one end, to the housing of the motor 1 and, by the other, to an auxiliary earth 4. The resistance of the coil is very high so that, when it acts, the current flowing is less than 0·1 A. This also makes the coil insensitive to big variations in the earthing resistance, for which a value of 800 ohms can be allowed. This permits of using the device with a very simple kind of earthing, and this is the great advantage of this system over the usual kind of protection earthings. Obviously, the point of earthing must have no conductive connection with the metal body to be protected as this would mean short-circuiting the coil and making it ineffective. Thus, any available earthing protection wire or an earthed neutral wire cannot be used as auxiliary earthing.

The coil is so designed that it will trip the switch, under usual conditions, at a voltage of about 20 V and, in the most extreme cases, at about 35 V. As these voltages cannot be dangerous to man, a very reliable protection against dangerous contact voltages has been created.

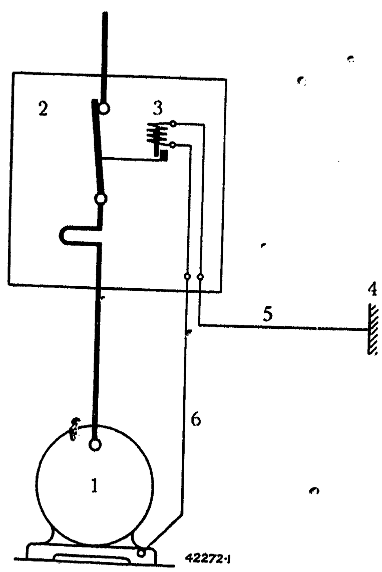

Fig. 1. — Fundamental diagram of connections of a switchbox equipped with fault-voltage tripping.

1. Motor.
2. Protecting switch.
3. Fault-voltage coil.
4. Auxiliary earths.
5. Earth wire.
6. Protection wire.

The fault-voltage tripping device itself (Fig. 2) is a very sensitive electro-magnet the armature of which is attracted under very slight excita-

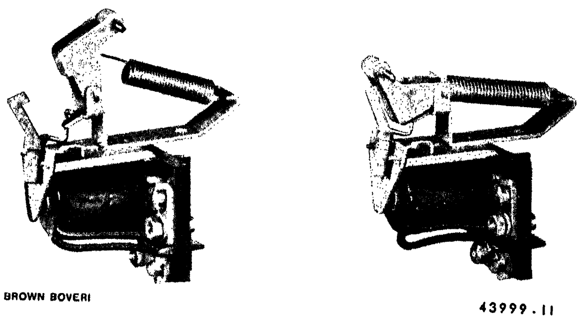

Fig. 2. — Fault-voltage tripping device with power-storage (spring) release.

On left: Tripped position. On right: Service position.

tion. In doing so it loosens the catch of a power-storage device, under the form of a wound-up spring, so that the releasing rod actuates the switch with great energy. In this way, the switch trips even under quite weak electric impulses. Nevertheless, the tripping device, itself, is insensitive to violent vibrations, which make it suitable for lodging in electro-magnet-operated switches. The coil itself is so made that it can stand up continuously to the weak current flowing through it when voltages which are too weak to be dangerous are impressed on the part being protected. The fault-voltage tripping device can be built into nearly all the protection switchboxes of Brown Boveri design (Figs. 3 and 4).

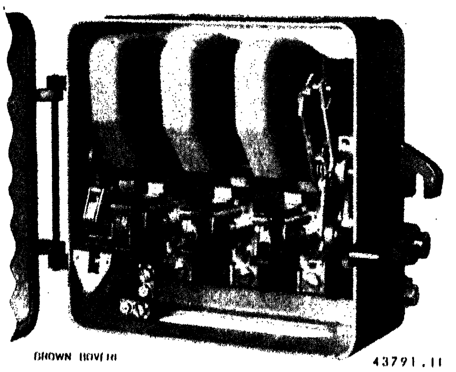

Fig. 3. — Switchbox Type N 2 with built-in fault-voltage tripping device.

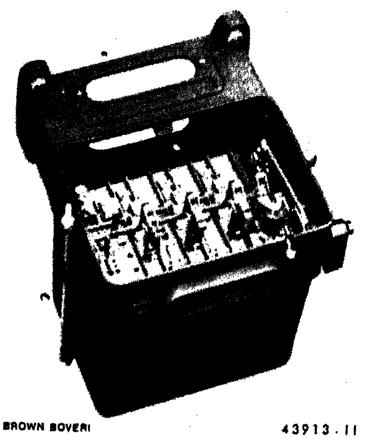

Fig. 4. — Star-delta switchbox, Type OSM 4 d, open, with built-in fault-voltage tripping device.

If the switch is tripped by a "fault voltage", it should be prevented from being reclosed without the fault having been, first, remedied, because, if it is reclosed at once, the dangerous state is re-established, if only momentarily. For this reason, the tripping device is, usually, so mounted that it can only be brought back to its service position after manipulation in the switch itself, with cover of switch removed for this purpose. In this way an overhaul of the defective plant will, obviously, be carried out by the skilled man who has been entrusted with the job.

It is intentionally that no push-button for testing is built into the switchbox, the object of which is to test the reliability of the fault-voltage tripping device. Apart from the fact that a test carried out by an unskilled person is, usually, valueless, the device, under this form, does not supervise protection wire 6 (Fig. 1) and this is the organ which is most easily damaged. Now, the danger lies, precisely, in damage to this part of the plant, as has been shown by investigations in Swiss power plants, which show that, of 26 accidents occurring over a period of several years, and due to insufficient protective earthing, 18 accidents are due to the rupture of the earthing wire or earthed neutral wire. Therefore, even when fault-voltage tripping is used, special attention must be given to the supervision of the protection wire and earthing wire.

If, nevertheless, an easy method of subsequent testing is insisted on, the testing push-button must be placed as is shown in Fig. 5. A change-over switch is secured directly on the motor housing to be protected and so connected that, in the service position, the protection wire leads to the motor housing. If the switch is laid over, the said conductor is cut off from the motor housing and connected, through a resistance, to a motor terminal, so that the protective device immediately trips the switch if the former is in order. A testing equipment of this kind includes the whole protective device and not

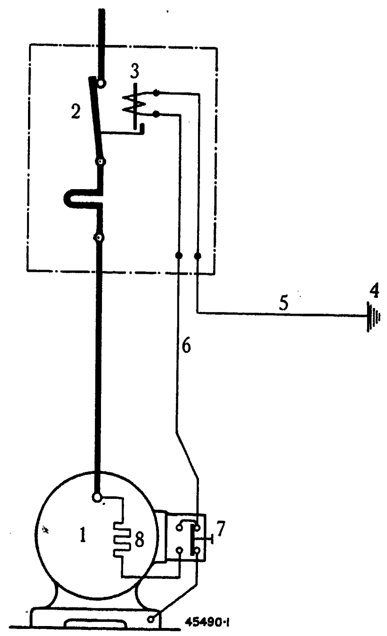

Fig. 5. — Connections of a protective switch with fault-voltage trip combined with push-button for testing.

1. Motor.
2. Protection switch.
3. Fault-voltage coil.
4. Auxiliary earth.
5. Earth wire.
6. Protection wire.
7. Testing push-button.
8. Testing resistance.

only a part of it. The resistance mentioned is so dimensioned that the lowest admissible tripping voltage appears across the coil terminals when the test is made, so that the tripping sensitivity of the protective device may be ascertained at the same time.

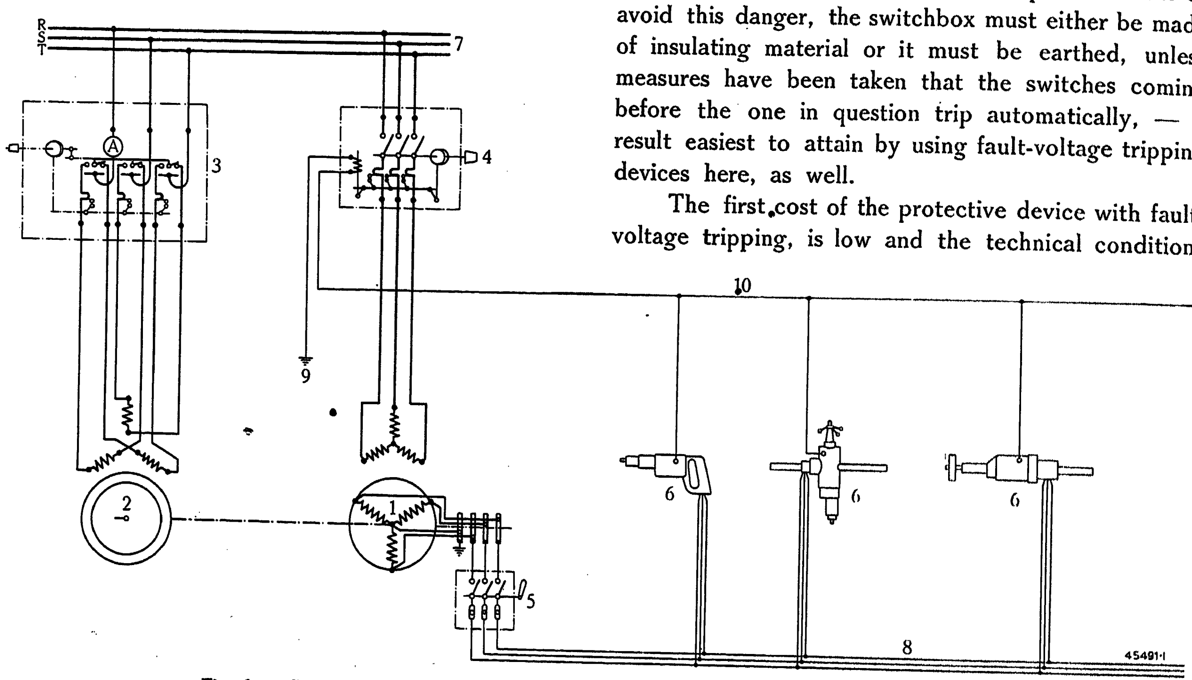

Fig. 6. — Connections of a plant using high-frequency tools, with fault-voltage protection.

1. Three-phase, frequency transformer for 200 V, 150 Hz.
2. Driving motor.
3. Star-delta motor-protection switch Type OSH 4d.
4. Motor-protection switch Type N 2 with fault-voltage trip.
5. Switchbox Type FC 2.
6. High-frequency tools.
7. Primary system.
8. Secondary system, 200 V, 150 Hz.
9. Auxiliary earth.
10. Protection wire.

In the utilization of the fault-voltage release as a protective device against dangerous contact voltage, possible regulations which may be in force in various countries must be taken into account. Speaking quite generally, it should be said that this protective system of connection can be used either as an independent measure against dangerous contact voltages or else to complete the earthing protection wire or earthed neutral wire. In the latter case, it is to be noted that protective earths or earthed neutral wires, as already mentioned when explaining Fig. 1, do not replace the auxiliary earth required by the fault-voltage tripping device neither must they be in conductive connection therewith. On the same grounds, when using a pumping set, for example, the water main of the pump must not be used as earthing conductor for the fault-voltage coil. In general, a copper plate placed in the earth and measuring 25×25 cm suffices as auxiliary earth, or else a galvanized iron pipe of 1—2″ bore sunk by 2 to 1 m in the ground.

Obviously, the switch equipped with fault-voltage tripping only protects those parts of the plant against dangerous contact voltages which are placed after the switch. If trouble develops on the supply-line terminals of the protective switchbox and if this puts its metallic housing under voltage, the dangerous contact voltage on the switchbox housing persists despite the fact that the switch is open. In order to avoid this danger, the switchbox must either be made of insulating material or it must be earthed, unless measures have been taken that the switches coming before the one in question trip automatically, — a result easiest to attain by using fault-voltage tripping devices here, as well.

The first cost of the protective device with fault-voltage tripping, is low and the technical conditions requisite to its proper functioning are easy of attainment, because no severe demands are made on the necessary earthing which has to be created. The preceding paragraphs explain the conditions which are usually decisive for the use of this protection. As practical fields of application, mention can be made of: — single and remote plants, in which neither an earthed neutral nor a protective earthing can be used, portable motors, electric tools, etc. Fig. 6 shows an example of the application of the protective device.

The fault-voltage tripping device built into the switchbox can, also, be used to advantage as an ordinary remote tripping device, especially in plants where, for certain reasons, it is impossible to use a closed circuit connection with a low-voltage coil. In such cases, the fault-voltage tripping device acts as an open-circuit tripping device, that is to say it acts through the momentary closing of a current circuit. It is also possible to have mutual electric interlocking of two or more switches at little extra expense; the opening or closing of one switch causing the automatic tripping of one or several other switches.

(MS 559) *S. Hopferwieser. (Mo.)*

NOTES.

Load balancing between three-phase shunt commutator motors running in parallel.

Decimal index 621. 313. 333. 016. 31.

WHEN motors having a shunt characteristic are rigidly coupled together through the machine they are driving, it is possible that a state of unequal loading of the said motors may occur. In the case of D. C. shunt motors, and according to the conditions of the case under consideration, the load can be equalized by relatively simple means, namely by equipping the motors with strong compound windings or by seeing that they have the same field voltage.

In the case of three-phase shunt commutator motors, however, which are coupled together, there is a decided tendency towards unequal distribution of load when the position of the brushes is not exactly the same, which, in the case of two motors, for example, and under bad conditions, may lead to one being completely unloaded while the other is correspondingly overloaded. Therefore, special measures are necessary to meet these service conditions, so that a proper distribution of the load on the motors may be attained. As is known, the speed and with it the load of rotor-fed shunt commutator motors can only be altered by displacing the brushes. Therefore, a device to balance the respective loads must act on the displacement of the brushes.

Brown Boveri have developed a controlling relay for this regulating device which acts on differences in load of the different motors and which closes the circuits of the brush-displacement motor, in one or the other sense, through the agency of auxiliary contactors, so that the brushes are displaced in the sense of a balanced load on the motors.

In the case of two motors coupled together, one control relay suffices, which regulates one of the two motors. In the case of a drive by several motors, each of these has its own relay which controls its output; the control relays being, then, linked up in polygone connection.

This regulating device is notably necessary in the case of the drive of double and of multiple rotary printing presses by three-phase shunt commutator motors, because this case is a typical example of the coupling of the driving motors. Modern multiple rotary printing presses are made up of three, four and more printing units each of which has got its own driving motor, which units are coupled together in any desired combination and according to the number of pages of the newspaper being printed, so as to form one machine. In this way, the driving motors of the units making up the whole are coupled together. Brown Boveri has designed the connections for rotary-press drives of this kind so that, when the push-button controls are connected in parallel, the requisite control relays for load distribution are automatically switched in.

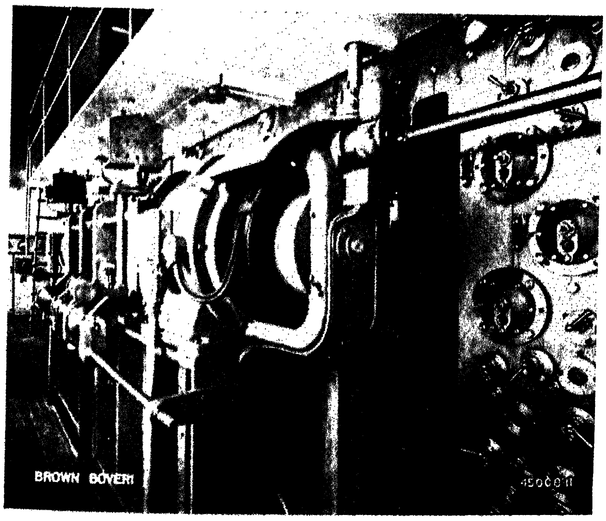

Fig. 1. — Drive of a double rotary printing press by two three-phase shunt commutator motors each of an output of 45 kW.

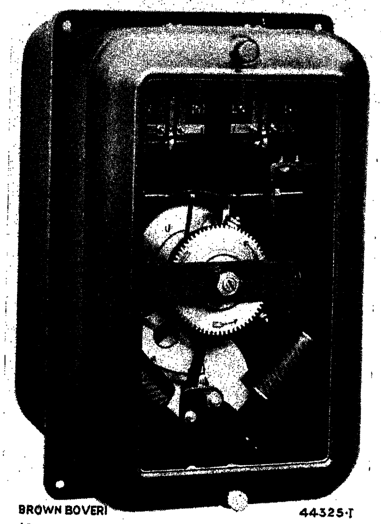

Fig. 2. — Control relay Type R 2/1.

Fig. 1 shows a double rotary press drive with two three-phase shunt commutator motors each of 45 kW output, the load on which is regulated in the manner described. The control relay is built into a switchboard cubicle seen in the background.

Fig. 2 shows the relay itself.

(MS 558) *A. Auer. (Mo.)*

Electric-boiler plant of the S. A. des Câbleries et Tréfileries, Cossonay (Switzerland).

Decimal index 621. 181. 646.

THIS electric boiler is designed for a maximum load of 4300 kW at 13 kg/cm^2 gauge pressure, for dry-saturated steam, 13,000 V, 50 Hz. The maximum production of steam, at a feed-water temperature of 70° C, attains about 6000 kg/h.

The feed water of this electric boiler plant is composed of about 70% condensate flowing back and of 30% make-up water. The latter is raw water of 7° German hardness which is softened in a Neckar softener down to 2° German hardness by a chemical process. The average specific resistance of the feed water at 20° C is about 5300 ohm-cm, the blow-down quantity when the boiler is subjected to full salt concentration is about 10% of the feed-water quantity.

The heat stored in the blow-down water is recuperated by leading the said water, first, to an expansion tank where the steam generated is carried to the water softener and used to heat up the raw water to about 70° C. There is a special valve with setting scale inserted on the blow-down pipe which allows of setting the corresponding blow-down quantity to every boiler load worked to.

Further, the boiler is equipped with an automatic pressure-regulating device which allows of maintaining the pressure at a practically constant value when the load fluctuates from 0 to 100% max. load. The constant pressure can be set, by hand, in advance, at the desired figure.

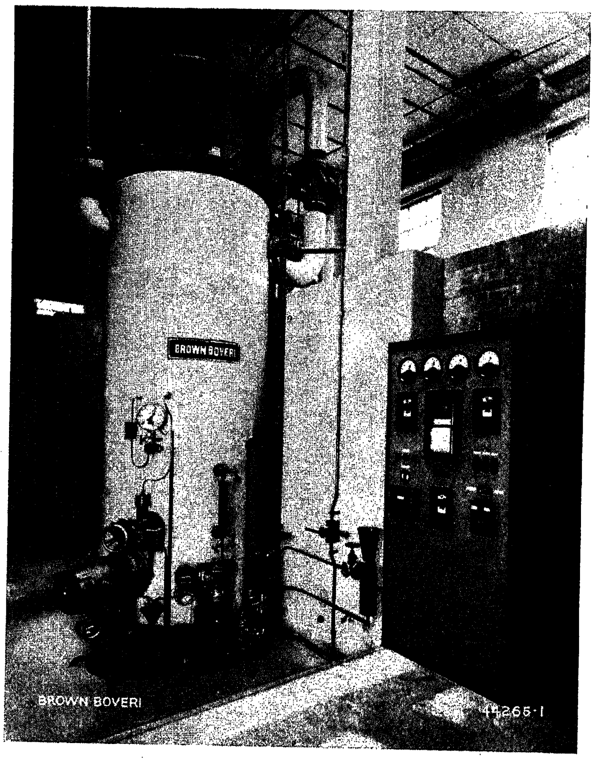

Fig. 1. — S. A. des Câbleries et Tréfileries Cossonay-Gare (Switzerland).
Electric boiler 4300 kW, 13 000 V, 14 kg/cm² abs.

The water-level regulating device, described in detail in leaflet 1420, serves to keep the water at constant level, to which end a very simple and reliable regulating device is utilized.

Fig. 1 shows the complete electric-boiler plant with the low-voltage switchgear panel. The latter, in close proximity to the boiler, carries the standard measurement instruments, the switchboxes of the pump motors, the apparatus for actuating the automatic regulating devices and the remote control for the main circuit breaker of the boiler.

The high-voltage switchgear is not in the same room as the electric boiler, but in a separate transformer station about 100 m away from the boiler. This sub-station contains the distribution of electric power for the whole works, the new Brown Boveri air-blast high-speed circuit breakers being used here as main breakers. The air-blast high-speed circuit breaker of the boiler is operated by remote control from the low-voltage switchgear board, return signals being made, in the usual way, by signal lamps.

As a rule, this electric-boiler plant works alone and it, then, operates automatically. However, parallel working with the existing coal-fired boiler is provided for, when the electric power supply available does not suffice to cover the steam requirements of the works. In this case, the boiler operates without automatic pressure regulation and its output is regulated by hand to a load set by the electricity works.

The electric-boiler plant has been working since the year 1936 and is operating to the entire satisfaction of the owners.

(MS 565) *E. Soldati. (Mo.)*

Vertical shaft three-phase motors with hollow shafts.

Decimal index 621.34 : 621.671.

It has become increasingly customary, in recent years, to couple vertical-shaft pumps rigidly to their driving motors instead of through a flexible coupling, as was formerly the case. This is done because it brings down the cost of the pump set, as the total vertical load is carried by the thrust bearing of the motor alone and a separate thrust bearing for the pump is eliminated. This design of vertical-shaft pump sets has been still further developed, especially by American firms, by carrying up the pump shaft through the length of the motor shaft, which is then made hollow, and by placing a special type of coupling above the thrust bearing of the motor, this instead of placing the coupling below the motor. There is an adjustable nut placed on the shaft above the coupling which allows of adjusting the height of the pump shaft, that is to say the relative position of the runner and the guide blading of the pump. Fig. 1 shows three motors of 18·5, 27 and 33 kW respectively, delivered for oversea plants, among a number of similar units of about the same outputs. The thrust bearing of the motor is lodged in its upper part. This is a ball bearing with oil lubrication. It is very accessible for inspection. The motors are of three-phase type with squirrel-cage rotors. They have four poles and are for connecting up to a low-voltage, three-phase supply system. The design is drip-water proof. As is seen in the illustration, the motor is, practically, entirely enclosed.

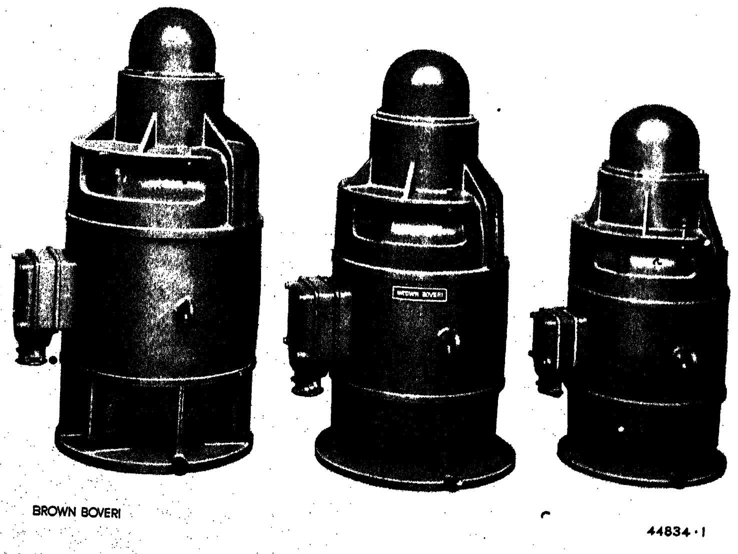

Fig. 1. — Three-phase vertical-shaft motors with hollow shafts.

(MS 568) *U. Vetsch. (Mo.)*

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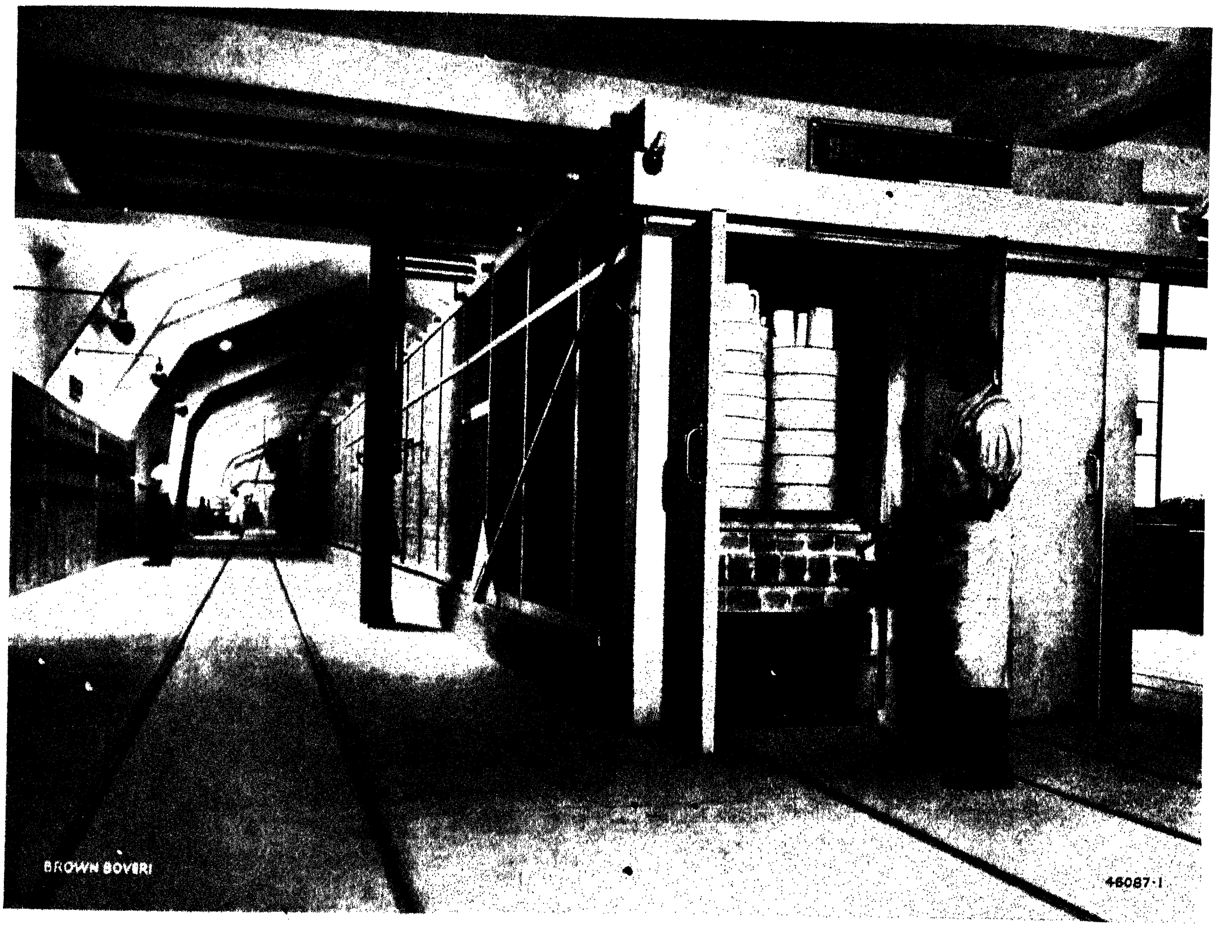
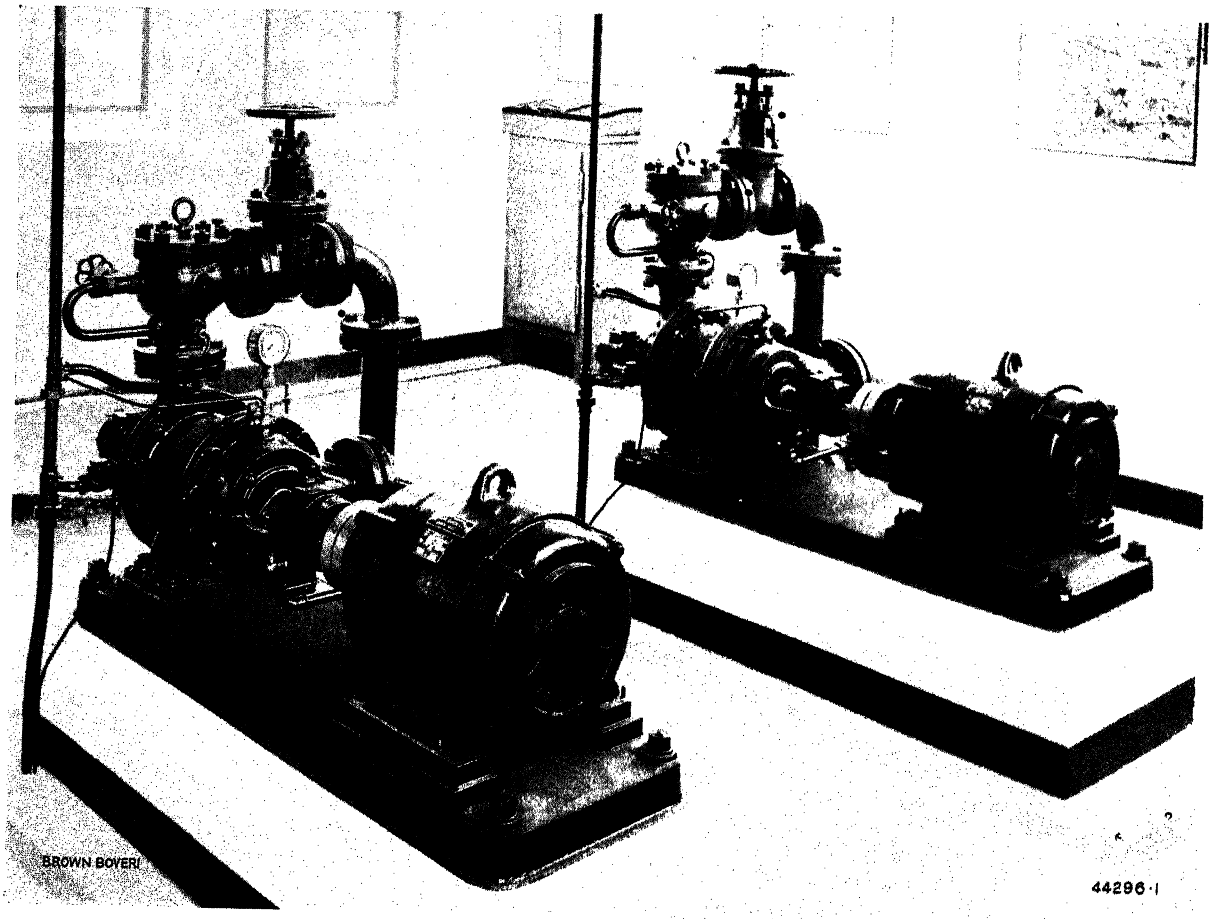


PORZELLANFABRIK LANGENTHAL A.-G., LANGENTHAL (SWITZERLAND). ELECTRIC DOUBLE-TUNNEL KILN.
Firing temperature 1410° C, total length about 100 m. Maximum production 30 m³ in 24 hours.

CONTENTS:

Printed in Switzerland

ELECTRIC
EQUIPMENT OF PUMPING STATIONS
for every kind of current and voltage



Automatic pumping station of the Town of Rolle (Switzerland).
Two pumps with motors having squirrel-cage wound rotors, for star-delta starting.

Equipments for automatic pumping stations

with

three-phase alternating and direct-current motors for control by float or remote water-level indicator, pressure switch or contact manometer as well as by time switch. Three-phase shunt commutator motors for automatic speed variation. - Automatic protective connections.

THE BROWN BOVERI REVIEW

THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)

VOL. XXIV | NOVEMBER, 1937 | No. 11

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CALCULATION OF THE OSCILLATIONS OF THE RECOVERY VOLTAGE AFTER THE RUPTURE OF SHORT CIRCUITS.

CHECKING OF RESULTS BY A CATHODE-RAY OSCILLOGRAPH AND BY MEANS OF A RESONANCE METHOD.

Decimal index 621.316.5.064.31.

I. INTRODUCTION.

THE important part played by the oscillations of the recovery voltage in the rupturing of short circuits is generally recognized. There are different methods available to determine the behaviour of the oscillations in question. In existing systems — for example, before new circuit breakers are put in — an experimental rupturing test can be carried out, to this end. Unfortunately, the necessary cathode-ray oscillograph is not always available when the test is made and, further, a straight short circuit has very disagreeable repercussions on the system investigated, which is the reason why tests of this kind are, often, forbidden by the responsible service authorities. The August number of The Brown Boveri Review contained an article on the experimental determination of the behaviour of the recovery voltage without the carrying out of short-circuit tests[1]. Of course, this method can only be used when the system is already built. In the case of a projected system, the behaviour of the recovery voltage can only be determined by calculation. Also, for the investigation of systems already built, it is important that there should be a reliable method of calculation available, because a calculation means much less disturbance to the operation of the system than does the carrying out of a measurement. Further, the calculation allows of a better determination of the extent to which the behaviour of the recovery voltage will be affected by any modification made on the system investigated.

The following paragraphs explain the principles of the calculation method developed by Brown Boveri. In order to check the method in question, a great number of cathode-ray oscillograms were carried out during the rupturing of short circuits. As most of the tests were carried out in the high-power testing plant at the Brown Boveri plant, the tests were, obviously, mostly laid out for being made in circuit-breaker testing plants. However, by far the greater number of problems handled here are met with, in exactly the same form, in the case of power stations and distribution systems. The only new factors inherent to the latter problems are the long transmission lines, which must be taken into account. In many cases, however, the said lines act, practically, like concentrated (lumped) capacities, so that exactly the same methods of calculation can be applied as in the case of circuit-breaker testing in the test plant.

The numerous tests carried out with the cathode oscillograph are not only useful for checking the calculation of natural frequency but they allow of determining the influence of the recovery voltage on the breaker and the effects of the breaker itself on the system. A separate treatise will, however, be devoted to this, later.

The chief difficulty in calculating the natural frequencies is presented by the capacities distributed along the windings of generators and transformers. In the case of a single generator or transformer, there is no difficulty in making the calculation in question. However, in a system of connections comprising several generators, transformers and, possibly, other inductivities and capacities, the exact calculation leads to very complicated equations. If it is found possible to substitute concentrated or lumped capacities of equal magnitude for the distributed capacities of the generators and transformers, the problem is considerably simplified. In the calculation of the oscillations in a system composed of lumped capacities and inductivities, solely, there are only algebraic equations to be dealt with, but if the said capacities are distributed the equations are of the transcendent kind. The first are easy to solve in mathematical form while the latter can only be solved graphically. As soon as there are distributed capacities at various parts of the system considered, the calculation becomes particularly complicated and difficult to grasp.

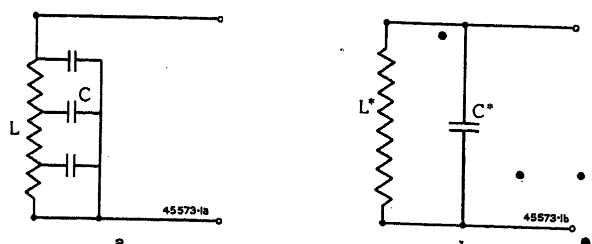
[1] Determination of the behaviour of the recovery voltage after rupturing short circuits, by means of a high-frequency resonance method.

Thus, the theory on which the calculation of the oscillations is based and which is set out here is, really, a theory of the replacement of the distributed capacities by equivalent lumped capacities. To begin with, the various methods of calculating equivalent lumped capacities will be discussed, and then the equivalent capacities, themselves, will be calculated for the most important systems of connections met with in practice, containing generators and transformers. This is not an absolutely complete treatise of every possible system of connection, but a discussion of the fundamental problems inherent to a big number of examples will be carried out so that it should be possible for the reader to calculate, in other cases, what the equivalent capacity should be. A later chapter will show how the oscillations can be calculated for a system of connections of lumped capacities and inductivities. Finally, systems of connections comprising generators and transformers with additional capacities and inductivities will be dealt with.

II. THE DIFFERENT METHODS OF CALCULATING LUMPED EQUIVALENT CAPACITIES TO TAKE THE PLACE OF DISTRIBUTED CAPACITIES.

(a) *Equality of admittances.*

A system of connections as in Fig. 1 a, in which a capacity C is distributed along an inductivity L is to be replaced by an "equivalent" system according to Fig. 1b, in which a lumped capacity C* is connected to the terminals of an inductivity L*, in parallel with the latter. These two connections will, obviously, be



Figs. 1a and b. — Arrangement of the distributed inductivities and capacities and equivalent diagram with lumped inductivities and capacities.

"equivalent" when their admittances are equal. In this case, there will be no difference to be discerned, from the terminals, between the two connections.

It is possible to determine, freely, one of the two magnitudes L* and C*. It is most convenient to arrange that

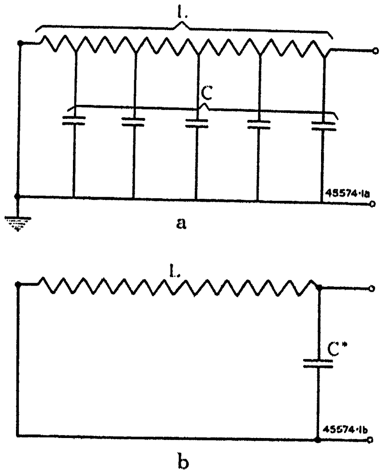
$$L^* = L \quad \ldots\ldots\ldots (1)$$

As in the case of the rupture of a short circuit the total inductivity of the system of connections is the deciding factor for the magnitude of the short-circuit current in that system, it is advantageous that the same inductivity should be inserted in the equivalent circuit as that placed in the real circuit.

Assuming this equality (1) the capacity C* in Fig. 1 b should be termed the "equivalent capacity for the distributed capacity C in Fig. 1 a".

At a given frequency, it is always possible to determine a capacity C* for which the equivalent circuit has got the same admittance as the original circuit. But the introduction of an equivalent capacity has only an advantage when its magnitude remains approximately constant over a certain range of frequency. Now, this is generally the case, so that it is allowable to talk of the equivalent capacity before knowing exactly how big the natural frequencies are going to be.

The calculation of the equivalent capacity will be explained by means of a simple example. Fig. 2 a represents a phase of a generator winding, with the inductivity L and the capacity C distributed along the winding (between winding and earth). An extremity of the phase, the neutral point, for example, is assumed to be earthed. The generator phase with its capacity against earth can be considered, in this case, as a long line, without loss, which is earthed at its end. For a line of this kind, as is known, the impedance, at the circuit frequency ω, amounts to



Figs. 2a and b. — Phase of a generator winding and equivalent diagram with lumped inductivity and capacity.

$$Z = j\sqrt{\frac{L}{C}}\,\mathrm{tg}\left(\omega\sqrt{LC}\right) \quad \ldots\ldots (2)$$

After some transformations the admittance is obtained, therefrom, and is expressed by

$$Y = \frac{\left(\omega\sqrt{LC}\right)\mathrm{ctg}\left(\omega\sqrt{LC}\right)}{j\,\omega\,L} \quad \ldots\ldots (3)$$

On the other hand, the equivalent system of connections according to Fig. 2b has an admittance of

$$Y^* = \frac{1-\omega^2 L C^*}{j\,\omega L} \quad \ldots\ldots\ldots (4)$$

By assuming equality of the two equations (3) and (4) the equivalent capacity is found to be

$$C^* = \frac{1 - (\omega\sqrt{LC})\,\mathrm{ctg}(\omega\sqrt{LC})}{\omega^2 LC} \cdot C \qquad (5)$$

The magnitude of the equivalent capacity is, thus, fundamentally dependent on the frequency ω. If, however, the curve of the equivalent capacity is drawn in function of the frequency (curve 1 of Fig. 3) it will be seen that it varies very slightly over a fairly wide range of frequency. While in the extreme case of very low frequencies the equivalent capacity is

$$C^* = \frac{C}{3} \quad \ldots\ldots\ldots \quad (5a)$$

it attains, for the fundamental oscillation of natural frequency of the generator phase ($f/f_o = 1$), the value

$$C^* = 0{\cdot}406\ C \quad \ldots\ldots \quad (5b)$$

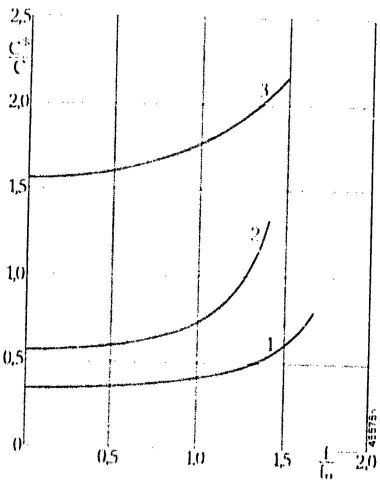


Fig. 3. — Equivalent capacity in function of the frequency impressed on the circuit for various generator connections.

1. For the arrangement shown in Fig. 2a.
2. For the arrangement shown in Fig. 6a.
3. For the arrangement shown in Fig. 7.

f. Frequency of the oscillation impressed on the circuit.

f_o. Natural frequency for the chosen arrangement of generator alone.

Thus, for frequencies below the fundamental frequency it can be assumed, with quite satisfactory approximation, that the equivalent capacity is a constant magnitude which can be calculated from equation (5a).

If there are choke coils or cables connected to the generator, the natural frequency of the whole system is considerably lower than that of the generator alone, in which case the approximation (5a) is quite satisfactory. But even if the natural frequency of the generator alone is calculated, by using the equivalent capacity according to (5a), the fault is only 10 %.

If a closer calculation is wished for in the case of some complex system in which the generator is inserted, the natural frequency of the entire system can be calculated by using equation (5a) and then the equivalent capacity belonging to this frequency can be deduced from Fig. 3, and, once this value is determined, the natural frequency of the system can be recalculated. However, as a rule, it is quite sufficient to calculate with the value $C^* = \frac{C}{3}$ given by equation (5a).

It should be specially mentioned that the equivalent capacity according to equation (5) has an indeterminate value for $\omega = 0$. In this case, as well as in the case of the formulae given below for the equivalent capacities, it is recommendable to develop the trigometrical functions in a series and to take the first member only into account. In this way equation (5a) was determined.

(b) *Equality of the natural frequencies.*

It is obvious to postulate that the connection systems according to Figs. 1a and b or 2a and b will be equivalent if their natural frequencies are equal. In the case of the natural frequency itself, the admittance is zero. If we determine the equivalent capacity for the example of the generator phase according to this definition, then, first, the admittance of the real circuit (Fig. 2a, equation 3) must be set down as zero, and the natural frequency deduced therefrom. The following results are attained:—

$$\omega_o = \frac{\pi}{2} \cdot \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{L \cdot 0{\cdot}406\ C}} \qquad (6)$$

$$f_o = \frac{\omega_o}{2\pi} = \frac{1}{4\sqrt{LC}} \quad \ldots\ldots \quad (6a)$$

If a comparison is made between the well-known value for the natural frequency of the equivalent circuit, Fig. 2b

$$\omega_o = \frac{1}{\sqrt{LC^*}} \quad \ldots\ldots\ldots \quad (6b)$$

and equation (6) it is seen, at once, that both circuits according to Fig. 2a and Fig. 2b have the same natural frequency if

$$C^* = 0{\cdot}406\ C \quad \ldots\ldots\ldots \quad (6c)$$

This value coincides, naturally, with that of equation (5b).

The method of same natural frequencies only leads to the correct value of the equivalent capacity in the case of the natural frequency of the generator, while the method of equal admittances allows of calculating the equivalent capacity for any frequency (impressed from without). If the method of equal natural frequencies is often used, despite its restricted validity, this is because it is the simpler of the two methods. In the example given, this is not so easy to see, but, in the case of complex connections, it constitutes a considerable simplification to be able to set down the nominator as equal to zero in the expression for the admittance (equation 3), this without being obliged to set down the whole expression for the admittance of the original circuit as being equal to the admittance of the equivalent circuit.

It may be asked why an equivalent capacity is, first, determined with the help of a natural frequency

when, really, it is a natural frequency itself, which is to be determined. The advantage is that the natural frequency need only be calculated for the generators alone from distributed capacities, while, later, for complicated connections, in which these generators form a part, the natural frequency can be calculated from the lumped capacities alone.

The equivalent capacity obtained by the method of equal natural frequencies is certainly not closer than that valid for limit cases of very low frequency (equation 5a). Obviously, for cases in which there are no inductivities and capacities connected to the generator the former equivalent capacity gives the exact natural frequency and the latter one does not. But this case is not an interesting one, because it is not necessary to determine an equivalent capacity by way of the natural frequency in order to calculate therefrom, again, the natural frequency. If, however, further inductivities and capacities are connected to the generator, the natural frequency of the whole system of connections becomes lower than that of the generator alone and then the equivalent capacity for the limit case of very low frequency, may even be more correct than the value attained by the method of equal natural frequencies. These *two* equivalent capacities are, thus, approximate magnitudes. The preference should, generally, be given to the one which it is easiest to calculate.

(c) *Equality of the stored energy.*

It can be proved that any circuit without losses, having two terminals, has the same admittance at a given frequency as a simple oscillating circuit as shown in Fig. 1b, on condition that both circuits have stored in them the same amount of electric energy at the same peak value of the terminal voltage and the same amount of magnetic energy at the peak value of the terminal current. On the basis of this knowledge, the equivalent circuit for any system of connections with distributed capacity and inductivity (as Fig. 4a, for example) can be calculated in so far as the current and voltage distribution along the extent of this circuit is known.

This method can be quite generally applied and especially at any frequency. In order to abbreviate, only the extreme case of low frequency is gone into; the method is very advantageous, here. At very low frequencies (as compared to the natural frequency) the current through the capacities in Fig. 4a is so low that it can be disregarded as compared to the current in the winding of the inductivity L. Therefore, the current in L is equal in value along the whole winding and the voltage against earth increases linearly from zero up to the terminal value U (Fig. 4b). Therefore, $L^* = L$ must be set down in order that the magnetic energy in the equivalent circuit should be equal to that in the real circuit. Further, as is known, when the voltage rises linearly, the electric power becomes: —

$$W_C = \frac{1}{2} \frac{U^2 C}{3} \qquad \ldots\ldots\ldots (7)$$

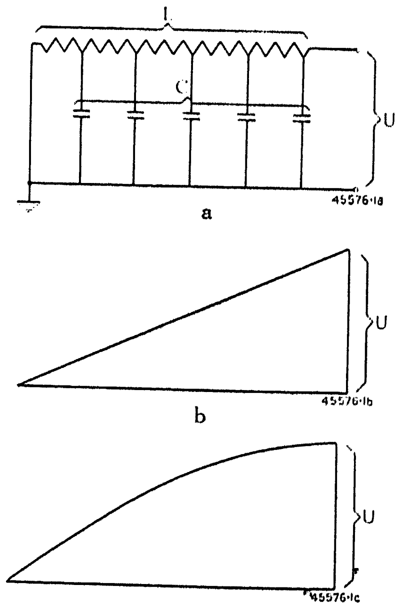
and has an equal value in the equivalent circuit when

$$C^* = \frac{C}{3} \qquad \ldots\ldots\ldots (7a)$$

is chosen.

This equation is the same as equation (5a) which was found by the admittance method (and also for the extreme case of very low frequency).

With complicated systems of connections, as well, the capacity current can be disregarded as compared to that flowing through the winding, for the extremely low frequency range. Therefore, the inductivity in the equivalent circuit is always of the same magnitude as in the real circuit. The voltage changes linearly along the length of each part of the winding which has no branches off it. Thus, the electric power and, therefrom, the equivalent capacity, is easy to calculate.



Figs. 4a, b and c. — Simple oscillating circuit with distributed capacity and inductivity.
(As, for example, a generator phase.)
a. Diagram.
b. Distribution of potential along the inductivity, for low frequencies.
c. Distribution of potential along the inductivity, for the fundamental wave of natural frequency.

The method of equality of inherent energy is, thus, very simple for very low frequencies. When this method is applied, in this special way, however, nothing is known of the behaviour of the equivalent capacity at higher frequencies. If it is necessary to know this, as well, the best way is to use the method of the equality of admittances.

It will only be added here that the method of the equality of inherent energy can furnish a clear explanation of the modification of the equivalent capacity in function of the frequency. Fig. 4 b shows the linear increase of voltage along the length of the winding of a generator phase when the frequency is very low. In the case of the fundamental natural frequency, the voltage distribution is represented by a quarter cycle of a sine function, as is generally

known (theory of long lines), and this is illustrated in Fig. 4c.

It will be seen, immediately, that with the same terminal voltage the electric energy in Fig. 4c is greater than that in Fig. 4b. Therefore, it is understandable that the equivalent capacity is bigger in the first than in the second case (compare to equation 5b and 5a or curve 1 Fig. 3).

III. THE EQUIVALENT CAPACITIES FOR GENERATORS.

(a) *General notes.*

For medium- and high-frequency oscillations, the leakage inductivity and not the synchronous inductivity is the deciding factor. This leakage inductivity is somewhat lower at high than at ordinary service frequencies as a result of the non-uniform distribution of flux in the iron, the difference, however, should not be very considerable as, in any case, the leakage field closes through the air, for the greater part. On the other hand, the leakage reactance diminishes somewhat, even at ordinary service frequencies, for very heavy currents, as a result of the saturation. In the following paragraphs, we always reckon, in determining the natural frequency, with the value of the leakage reactance which is obtained from a three-pole sudden short circuit across the terminals at about $^3/_4$ of the rated voltage.

In reality, in the case of stray reactances, a difference must be made between the values for the three systems of symmetrical components. As soon as the said three values are unequal, it is no longer admissible to calculate as though the leakage reactance of each phase was not interlinked to those of the other phases. The exact calculation is, then, best carried out by the method of symmetrical components as Evans and Monteith have done.[1]

However, the reactance of the negative-sequence system is, practically, equal to that of the subtransient reactance of the positive-sequence system and, in the case of the generator in the Brown Boveri high-power testing plant, the reactance of the zero-sequence system is practically the same as the subtransient reactance. When these three reactances are of equal magnitude, the leakage reactance of the generator can be represented by three choke coils inserted on the three phases. In this case, it seems simpler not to treat the problem according to the method of symmetrical components. It would be an unnecessary complication to decompose the system of connections being investigated into its three symmetrical components, when the same reactance is found in each of the said components.

In order, however, to be able to estimate the error made when the simplified method is applied, in the case of the reactances of the three symmetrical components not being of equal magnitude, the example has been taken for the first phase of a three-phase line to earth short-circuit to be extinguished in the case where the reactance of the zero sequence system is only half the magnitude of the subtransient reactance of the positive-sequence system. The exact calculation according to the method of symmetrical components gives — in the extreme case of very low frequency — under these conditions, as well, exactly the same equivalent capacity as the approximation method described (curve 2, Fig. 3). However, the curve rises somewhat less steeply with increasing frequency than does curve 2.

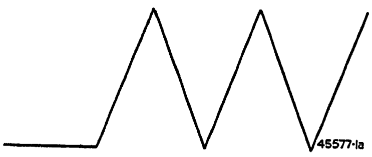
As we recommend calculating with the equivalent capacity, which is valid for very low frequencies, for the whole range of frequencies below the natural one and to use curve 2 simply to estimate the fault, the actual error incurred can, only, be smaller than that of the estimation. It, therefore, seems justifiable to use the simplified method and not to apply the considerably more complicated method of symmetrical components.

The capacity of a generator winding is, mainly, between the winding and the iron. The mutual capacity between the different phases is very small; further, the capacity between the individual coils of one phase is small as compared to the capacity to earth. The coils which are not lodged in the same slot have, also, a relatively low mutual inductivity. Thus, each phase of the generator winding can be considered, with quite sufficient approximation, as being a series connection of inductivities which are not coupled together and which possess an evenly distributed capacity to earth. In other words, each phase winding behaves somewhat as would a long line. As a matter of fact, the investigation of travelling wave phenomena in the windings of machines goes to show that this assumption is correct.

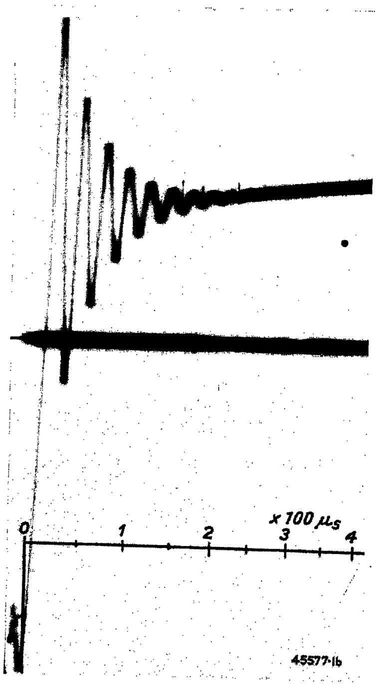
Basing on this assumption, the equivalent capacity for a single generator phase was already calculated in Chapter II. It should only be added here that the equivalent connection according to Fig. 2 b has only got one natural frequency, while the original system of connections according to Fig. 2 a has all the odd harmonics apart from the fundamental wave. As the exact calculation shows, the amplitude of the nth harmonic is, only, $1/n^2$ times as big as the fundamental wave. The resultant oscillations of the recovery voltage is represented by a saw-tooth curve (Fig. 5 a). As the higher harmonics are relatively small

[1] System Recovery Voltage Determination by Analytical and A. C. Calculating Board Methods. Electr. Engineering of June, 1937, page 695.

and as the average rising speed of the voltage for the first half cycle of the saw-tooth curve is exactly the same as for the fundamental wave alone (when both peak values are the same) there is no disadvantage when the equivalent diagram of Fig. 2 b does not take the higher harmonics into account.



a



b

Figs. 5a and b. — Recovery voltage for a generator phase, according to diagram Fig. 2a.

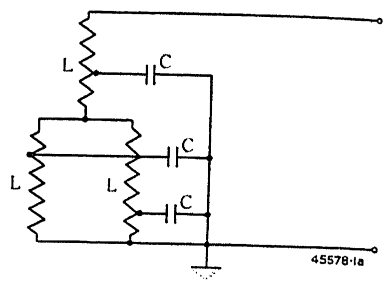
a. Theoretical curve (no damping).
b. Cathode-ray oscillogram.

The cathode-ray oscillogram of Fig. 5 b shows that the recovery voltage really has a saw-toothed characteristic. This oscillogram is valid for a generator phase according to the diagram of Fig. 2a, but, in the case where the relatively small capacity of a transmission line is connected to the terminals. The oscillogram allows of deducing a natural frequency of 40,000 Hz. Calculations according to equation (6 a) give a frequency of 44,200 Hz for this system of connections.

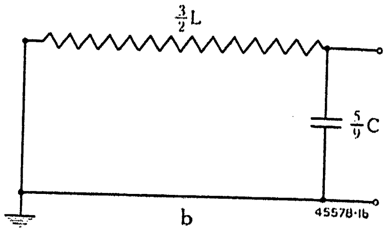
(b) *Different connections of a generator.*

The natural frequency and, also, the equivalent capacity of a generator is not an invariable magnitude. It depends on whether the generator is star- or delta-connected. Further, it depends on whether the winding is earthed at all or what points of the winding are earthed. Finally, in general, the natural frequency differs for the first and last phase extinguished in the case of a three-phase line short-circuit; in the case of a three-phase line to earth short-circuit it is other than a pure three-phase line short-circuit, and so on. All these cases must be treated separately.

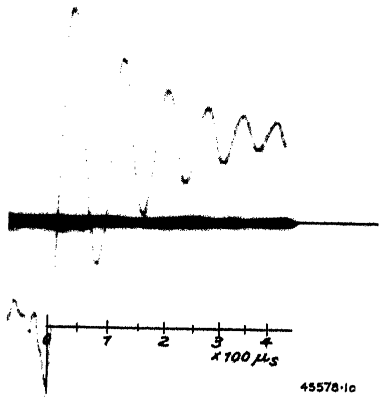
If a generator winding is star-connected, and not earthed, the diagram shown in Fig. 6 a is obtained for the first-extinguishing phase of a three-phase line to earth short-circuit. The rupture point of the breaker at which the short-circuit current is suppressed at the moment of investigation is represented by two open terminals. The two phases through which current still flows after the extinction of the first phase are connected together in Fig. 6 a.



a



b



c

Figs. 6a, b and c. — Determination of the recovery voltage for the first phase extinguished of a three-phase line to earth short-circuit with star connections of the generator.

a. Diagram.
b. Equivalent diagram for low frequencies.
c. Cathode oscillogram.

The winding behaves like a series connection of two lines one with the constants L and C, the other with L/2 and 2 C. This is short-circuited at its extremity. If the equations are established for both lines and if the limit conditions are mutually adjusted, the admittance of the whole system of connections will be found to be

$$Y = \frac{(\omega\sqrt{LC})\,\mathrm{ctg}(\omega\sqrt{LC}) - \frac{1}{2}(\omega\sqrt{LC})\,\mathrm{tg}(\omega\sqrt{LC})}{j\,\omega\,\frac{3}{2}\,L} \qquad (8)$$

This value is then set down as equal to the admittance of an equivalent circuit according to Fig. 1 b in which $L^* = \frac{3}{2}$ L is chosen so that the inductivity of the equivalent circuit coincides with that of the original one. This leads to an equivalent capacity of

$$C^* = \frac{1-(\omega\sqrt{LC})\mathrm{ctg}(\omega\sqrt{LC})+\frac{1}{2}(\omega\sqrt{LC})\mathrm{tg}(\omega\sqrt{LC})}{\omega^2 LC}\cdot\frac{2}{3}C \quad \ldots\ldots (8a)$$

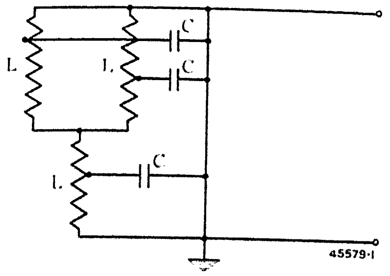


Fig. 7. Connection of generator with one phase earthed.

This value is inserted in Fig. 3 in function of the frequency (curve 2). For very low frequencies, a series development leads to the limit value

$$C^* = \frac{5}{9}\,C \quad (8b)$$

so that for Fig. 6 a the equivalent Fig. 6 b is valid. Fig. 6 c shows the behaviour of the recovery voltage for the case in point (for the ordinary arrangement of the Brown Boveri high-power testing plant with the cables between generator and breaker). The natural frequency deduced therefrom amounts to 14,000 Hz, while the figure calculated is 16,000 Hz.

In the case of connections as shown in Fig. 7 the equivalent capacity is calculated in quite analogous manner to the case just described. Its characteristic is shown in Fig. 3 (curve 3). Its limit value for very low frequencies is

$$C^* = \frac{14}{9}\,C \quad \ldots\ldots\ldots (9)$$

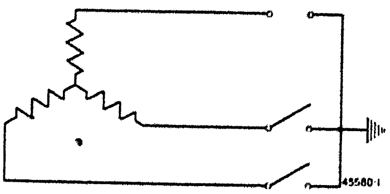
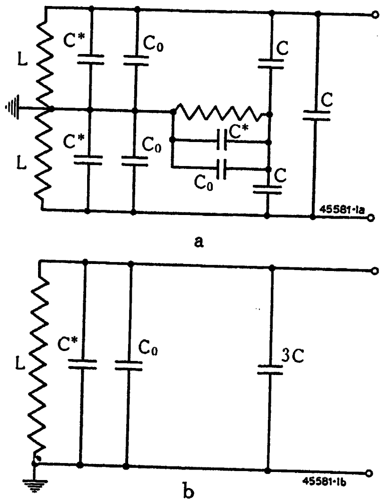


Fig. 8. Diagram for the last phases to be extinguished in the case of a three-phase line short-circuit with star connection of the generator.

If, now, the amounts of stored electric energy are compared at the same terminal voltage, it will be clear why the system of connections according to Fig. 7 has a bigger equivalent capacity than that of Fig. 6 a. In the first case, the capacities of two phases (total 2 C) are subjected to a higher voltage than the capacity C of the third phase, while the opposite takes place in the second case.

In the case of the last phase extinguished of a three-phase line to earth short-circuit (Fig. 8) the star point is at the potential of the earth for reasons of symmetry. The upper phase in the figure, the current through which was ruptured earlier, is, also, as far as the oscillating phenomena is concerned, quite at earth potential for symmetrical reasons and thus is quite inactive. The behaviour of the recovery voltage is, here, exactly the same as in the case of a single phase, one end of which is earthed. The equivalent capacity is also the same and is to be inserted in parallel with each of the two active phases.

If, in this system of connections (Fig. 8), the neutral point is permanently earthed, nothing is changed as regards the equivalent capacity and natural frequency as compared to the case examined previously.



Figs. 9a and b. — Equivalent diagram for the last phases to be extinguished in the case of a three-phase line short-circuit with star connection of the generator and using cables.

If the circuit breaker is connected to the generator through a cable, the distributed capacity of each generator phase can be replaced, as well, by the equivalent capacity according to equation (5 a), in which case, the capacities of the cable must be added at the terminals, so that Fig. 9a results. In this figure, C_o and C are partial cable capacities, the first against earth, the second between two phases. In this case as well, the phase ruptured already (the middle one in Fig. 9 a) carries no current when the oscillations of the recovery voltage occur, for reasons of symmetry and it remains at earth potential along its whole length (generator winding and cable). Thus, each half can be reduced to Fig. 9 b which represents a simple oscillating circuit. The natural frequency of the whole arrangement is equal to that of each half. For the high-power testing plant, calculation effected in this way lead to 19,900 Hz while the resonance method[1] gives a measured figure of 20,000 Hz.

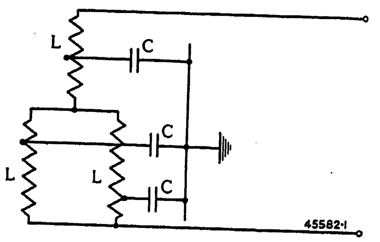


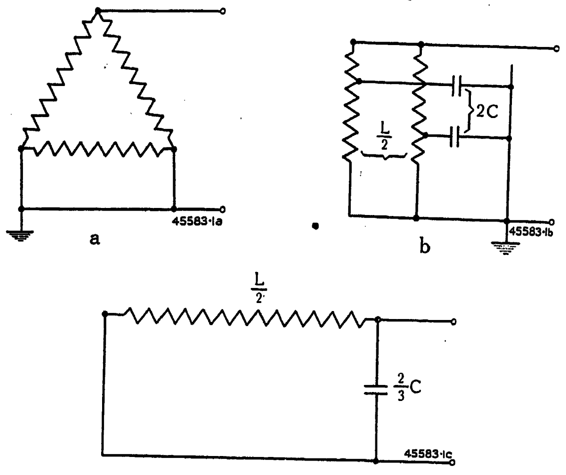
Fig. 10. — Diagram for the first phase to be extinguished of a three-phase line short-circuit with star connection.

Assuming that the neutral point of the generator is earthed, and considering the moment the first phase of a three-phase line to earth short-circuit is extinguished, it will be seen that two phases find themselves short-circuited through being earthed at both ends and, thus, play no part in the production of oscillations. The calculation has then

[1] See foot note on page 283.

to be made for one single phase only, earthed at one end. When ordinary cable is used, a natural frequency of 23,700 Hz is calculated, while with the resonance method 21,800 Hz is measured.

If, in the case of a three-phase line short-circuit, neither the neutral point of the generator nor the point of the short circuit itself, are earthed, then the diagram of Fig. 10 is valid for the first phase to be extinguished. As no point of the winding is permanently earthed, the current which flows over the capacities to earth, from one part of the winding, must flow back again through the capacities of the



Figs. 11 a, b and c. — Diagram and equivalent diagram for the first phase to be extinguished of a three-phase line to earth short-circuit, with delta connection of the generator.

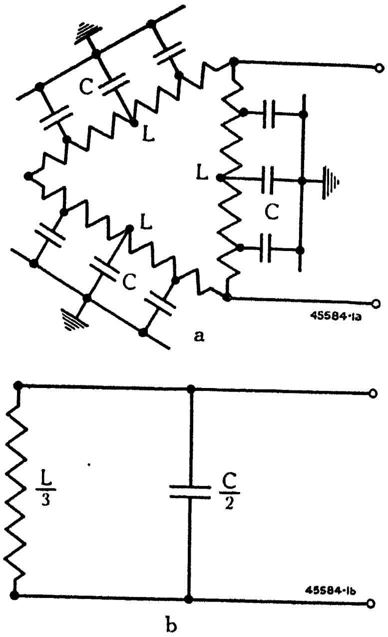
other parts of the winding. It will be easily understood that this is only possible if the neutral point is at the potential of the earth. This is also valid when cables are connected symmetrically to the generator. The equivalent capacities are, thus, exactly the same as in the case of the neutral point being permanently earthed, that is:—

$$C^* = C/3$$

in parallel to each phase and between terminals and neutral point.

This example shows that, in the case of systems of connections which are not earthed, the first thing to be ascertained is which point of the system is at earth potential. Then, the equivalent capacity is exactly the same as though the point in question were permanently earthed. This method allows of solving, easily, all problems presented by other layouts which may occur with star connections of the generator.

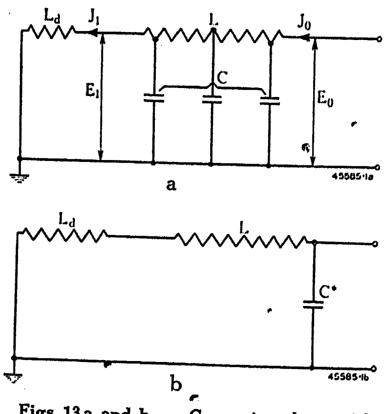
In the case of the delta connection, Fig. 11 a is valid for the first phase to be extinguished of a three-phase line to earth short-circuit. The lower phase remains short-circuited and plays no part in the production of the oscillations. Therefore, the diagram can be represented as in Fig. 11 b. The arrangement of the distributed capacities is the same as in the first example of a single generator phase earthed at one end. Thus, the equivalent diagram 11 c is easy to establish. For the high-power testing plant (generator with cables) the calculated natural frequency from this diagram is 25,300 Hz while the cathode oscillograph shows 23,500 Hz.



Figs. 12a and b. — Diagram and equivalent diagram for the last phases to be extinguished of a three-phase line short-circuit with delta connection of the generator.

If the point of short circuit is not earthed, the equivalent capacity in the connection for the first extinguished phase, for the limit case of very low frequencies, is found to have the value $C^* = C/3$, that is only half as much as in Fig. 11 c. This value is valid on the assumption that cables or transmission lines, if any, are symmetrical.

Fig. 12 a is valid for the last phases extinguished, in delta connection. For reasons of symmetry, the middle points of both parallel branches are at earth potential. It is easy to establish the equivalent diagram of Fig. 12 b for each half of this symmetrical diagram. In this case, calculation shows a natural frequency of 33,100 Hz in the ordinary layout with cables, while the resonance method gave a measured value of 33,300 Hz.



Figs. 13 a and b. — Generator phase with choke coil on the earth side.
a. Diagram.
b. Equivalent diagram.

(c) *A generator phase with choke coils.*

A phase L of a generator winding is assumed to be connected in series with a choke coil L_d and the whole system earthed on one side. The capacities

of the coil are much smaller than those of the generator and are not taken into account, here. If the choke coil is on the side which is not earthed, that is to say if one end of the generator winding is straight earthed, the equivalent capacity of the generator, which is to be connected in parallel to L, is to be calculated according to the formulae given in the second chapter.

If, on the other hand, the choke coil is inserted on the earthed side, as is shown in Fig. 13a, the equivalent capacity must be modified, because, assuming the same terminal voltage, the distributed capacity C is now at a higher mean voltage than when one end of the generator phase is straight earthed. Therefore, the equivalent capacity must be recalculated, in this case.

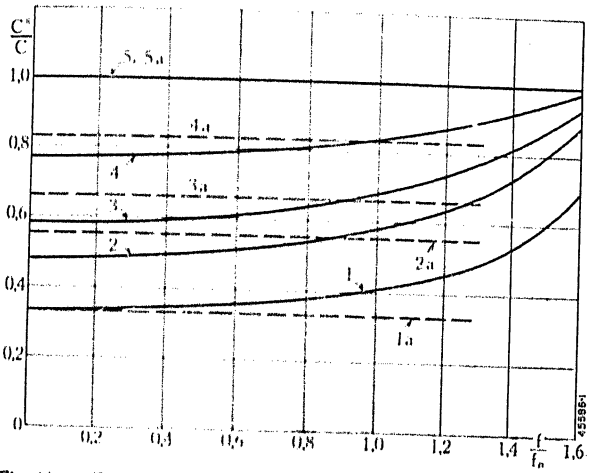


Fig. 14. Equivalent capacity of diagram Fig. 13, in function of the impressed frequency for various values of $\frac{L_d}{L}$.

1 to 5. Exact value of C*/C according to equation (12).
1a to 5a. Approximate value according to equation (14).
1 and 1a for $\frac{L_d}{L}$ 0
2 and 2a " " 0·5
3 and 3a " " 1
4 and 4a " " 3
5 and 5a " " ∞
L_d. Inductivity of choke coil.
L. Short-circuit inductivity of the generator phase.
C. Distributed capacity of the generator phase to earth.
C*. Equivalent capacity for C applied at circuit-breaker terminals.
f. Frequency of oscillations impressed.
f_0. Natural frequency of fundamental wave for the arrangement shown in Fig. 13a.

If the equation for long lines is applied to the generator phase (L, C) the result is:

$$\left.\begin{aligned} E_0 &= E_1 \cos(\omega\sqrt{LC}) + jJ_1\sqrt{\frac{L}{C}}\sin(\omega\sqrt{LC}) \\ J_0 &= J_1 \cos(\omega\sqrt{LC}) + jE_1\sqrt{\frac{C}{L}}\sin(\omega\sqrt{LC}) \end{aligned}\right\} \quad (10)$$

By division of these two equations the admittance Y of the diagram according to Fig. 13a is found. If, further, it is taken into account that

$$\frac{E_1}{J_1} = j\,\omega\,L_d \quad \ldots\ldots\ldots (10a)$$

the following result is reached

$$Y = \frac{\cos(\omega\sqrt{LC}) - \omega\,L_d\sqrt{\frac{C}{L}}\sin(\omega\sqrt{LC})}{j\,\omega\,L_d\cos(\omega\sqrt{LC}) + j\sqrt{\frac{L}{C}}\sin(\omega\sqrt{LC})} \quad (11)$$

If this expression is set down as equal to the admittance of the equivalent circuit in Fig. 13b, the equivalent capacity can be calculated by:—

$$C^* = \left\{\frac{1}{\omega^2 LC}\cdot\frac{L}{(L+L_d)} + \frac{L_d(\omega\sqrt{LC}) - L\,\mathrm{ctg}(\omega\sqrt{LC})}{L(\omega\sqrt{LC}) + L_d\,\omega^2 LC\,\mathrm{ctg}(\omega\sqrt{LC})}\right\}C \quad (12)$$

This expression is shown graphically in Fig. 14, C*/C being drawn in function of the frequency, for different values of the fraction L_d/L. The reference magnitude f_0 represents, here, the natural frequency of the system of connections of Fig. 13a. Curve 1 coincides with curve 1 of Fig. 3.

It will be seen that the equivalent capacity, for frequencies between zero and the natural frequency only changes slightly and that, in this range, it is the bigger the greater the ratio L_d/L. For very low values of the ratio in question, the voltage increases along the generator phase approximately linearly, from zero up to the terminal voltage, so that, approximately:—

$$C^* = \frac{C}{3} \quad \ldots\ldots\ldots (12a)$$

For very big values of L_d/L, on the contrary, the whole generator phase is, practically, at the same potential which is then equal to the terminal voltage.

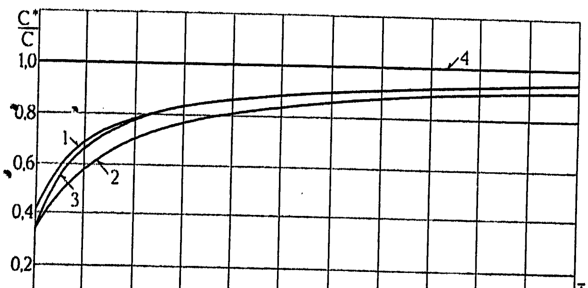


Fig. 15.—Equivalent capacity for diagram of Fig. 13 in function of $\frac{L_d}{L}$.

1. For the fundamental natural frequency of the diagram, calculated according to the method of equal natural frequencies (equation 13).
2. For the limit case of very low frequencies, calculated according to the method of equal energy stored (equation 12c).
3. For the natural frequency of the diagram in the limit case in which the former is very low (approximation equation).
4. Asymptotes to curves 1 to 3.

L_d. Inductivity of choke coil.
L. Short-circuit inductivity of the generator phase.
C. Distributed capacity of the generator phase to earth.
C*. Equivalent capacity for C applied at circuit breaker terminals.

For this reason, the distributed capacity acts with its full value, here

$$C^* = C \quad \ldots\ldots\ldots \quad (12b)$$

If it is desired to calculate the equivalent capacity by the method of equal natural frequencies, the nominator in the equation of the admittance (equation 11) must be set down as equal to zero and the natural frequency must be calculated from this. In this way the following equation is attained

$$\operatorname{ctg}(\omega\sqrt{LC}) = \frac{L_d}{L}(\omega\sqrt{LC}) \quad \ldots \quad (13)$$

This equation can only be solved graphically or tentatively with the assistance of trigonometrical tables. If, now, the fundamental natural frequency is set down as being equal to the natural frequency of the equivalent circuit Fig. 13b, the equivalent capacity C^* can be determined. The values thus determined are shown in function of L_d/L in curve 1 of Fig. 15. Obviously, they coincide with the values in Fig. 14 for $f/f_0 = 1$.

For the limit case of very low frequency (Fig. 14 for $f/f_0 = 0$) the equivalent capacity is determined by a series development of equation (12)

$$C^* = \frac{3\,L_d^2 + 3\,L_d\,L + L^2}{3\,L_d^2 + 6\,L_d\,L + 3\,L^2} \cdot C \quad (12c)$$

The same value can, of course, be determined by the method of equal energy stored. Equation (12c) is represented, graphically, by curve 2 in Fig. 15.

Curve 3 of this figure was determined as follows:— equation (13) can be simplified by developing the ctg function in a series and by taking only two members into account, as long as $(\omega\sqrt{LC})$ is of small magnitude, i. e. when the natural frequency of the whole system of connections of Fig. 13a is low as compared to the natural frequency of the generator phase, alone. This gives the following expression of the equivalent capacity:—

$$C^* = \frac{3\,L_d + L}{3\,L_d + 3\,L} \cdot C \quad \ldots \quad (14)$$

The condition named is only satisfied, however, when $L_d \gg L$. It is surprising to note that equation (14) also coincides fairly correctly for low values of L_d/L with the exact values of the equivalent capacity valid for the natural frequency. The curves 1 and 3 of Fig. 15 only deviate from each other by about 2%, for example, at the point $L_d = L$.

In order to show in what range of frequency the equivalent capacity reckoned according to the equation (14) coincides satisfactorily with the exact value according to equation (12), the former values are also shown in Fig. 14 (dotted straight lines 1a to 5a). This shows that the simple equation (14) gives a quite acceptable approximation for frequencies between zero and the first natural frequency of the system of connections according to Fig. 13a. This approximation is closest for frequencies near the natural frequency of the system, for big values of L_d/L (approx. $L_d/L \geq 0{\cdot}5$); for low values of L_d/L, on the contrary, it is more correct for low values of the frequency. This is, precisely, the desired character. Therefore, in what follows calculations are always made according to equation (14). For the limit case, $L_d/L = 0$ the equation coincides with equation (5a), which it was recommended to use for a generator phase straight earthed, without choke coil.

If, now, a cable is inserted between the choke coil and the generator phase, the diagram of Fig. 16 is valid, C_1 being the capacity of the cable. There is no difficulty, in this case, in determining the exact equation for the admittance and, this being done, in determining the equivalent capacity for C, by any method described in Chapter II.

In most cases, a simple approximation method is sufficient. Notably, when the natural frequency of the whole system of connections is low, as compared to the natural frequency of the circuit (L_d, C_1), the current through C_1 is much smaller than that through L_d. In this case, the voltage distribution along L_d and L is the same as in Fig. 13a and the equivalent capacity can be calculated by equation (14). The frequency conditions in question are always satisfied when the generator capacity C (along with an eventual other capacity connected to the terminals) is considerably greater than the capacity C_1.

In the other extreme case, in which a natural frequency of the whole system is considerably greater than the natural frequency of (L_d, C_1) the effect of C_1 on these oscillations is that of a short circuit. Then $C^* = C/3$.

(d) *Different generator connections with choke coils.*

In the case of star connection of a generator winding, the arrangement of the generator phases is symmetrical, for the last phases to be extinguished of a three-phase line short-circuit (whether the short circuit be one to earth or not). If, further, the choke coils, lines, cables, etc. connected to the generator are the same in all phases, then the whole system is sym-

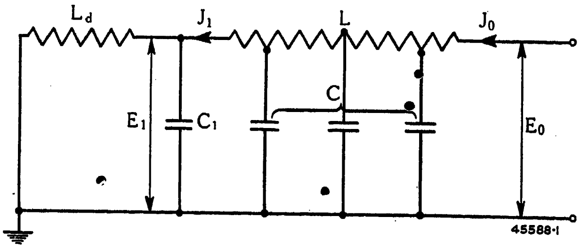


Fig. 16. — Diagram of connections for a generator phase with choke coil and cables inserted between them.

metrical. Therefore, the neutral point of the generator windings is at earth potential, this whether it be permanently earthed or not. Thus, the capacity of each generator phase, C, can be replaced by a lumped one $C^* = C/3$ connected in parallel to the inductivity L.

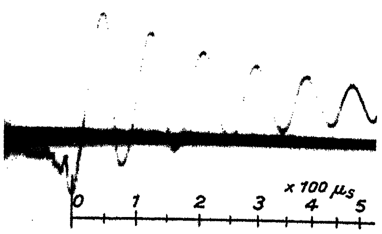
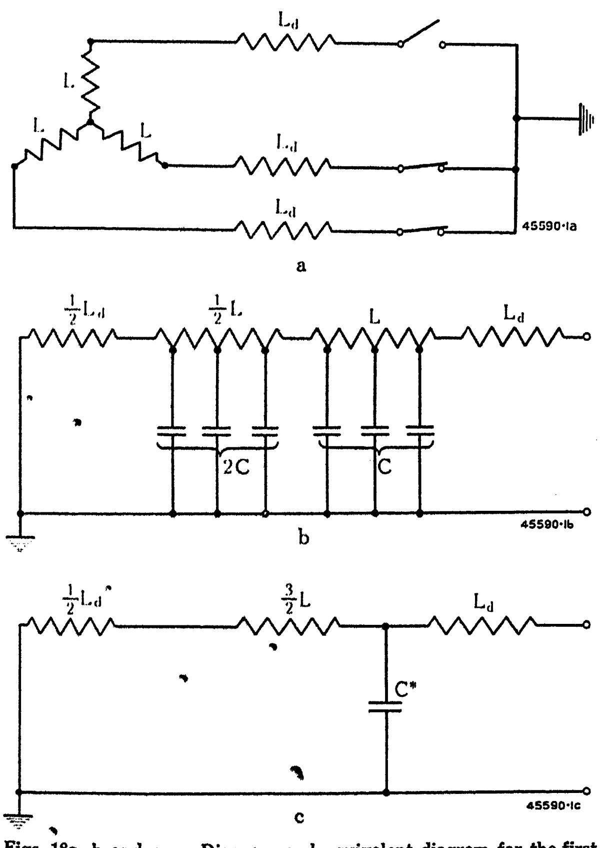


Fig. 17. — Cathode-ray oscillogram of the recovery voltage for the first phase to be extinguished in the case of a three-phase line to earth short-circuit on the generator of the high-power testing plant, where cables are used up to the test bed.

Connection of the generator in star and utilisation of three choke coils on the free phase of the generator.

The conditions for the first phase to extinguish of a three-phase line to earth short-circuit are quite different. As long as there are no choke coils inserted on the earthed phases, the equivalent diagram of Fig. 6b is valid for the generator (the neutral point being assumed as not earthed). The equivalent capacity to be inserted between the terminal of the free generator phase and the earth is determined by means of equation (8b). Choke coils in series with the free generator phase as well as cable capacities, if any, have no influence on the equivalent capacity of the generator. In the case of the high-power testing plant with its ordinary cable layout, calculations of this kind lead to natural frequencies of 12,600 and 31,500 Hz, in the case of three choke coils of each 0·318 mH being connected in series with the free generator phase. With the resonance method, frequencies of 12,400 and 26,500 Hz were measured. For the lower frequency the results of the two methods agree very well, indeed. The somewhat greater divergence observed at the higher frequency has no importance as its calculated amplitude is only 1·7 %. (Chapter V will show how the two natural frequencies and amplitudes thereof are calculated, after all the distributed capacities have been replaced by lumped ones). Fig. 17 shows the corresponding cathode oscillogram. This reveals a natural frequency of 12,500 Hz. The oscillogram does not reveal any higher frequency and it, thus, confirms the calculation which predicts a very low amplitude for the higher frequency.



Figs. 18a, b and c. — Diagram and equivalent diagram for the first phase extinguished of a three-phase line to earth short-circuit on the generator of the high-power testing plant, with evenly distributed choke coils among the three phases.

Generator connected in star.

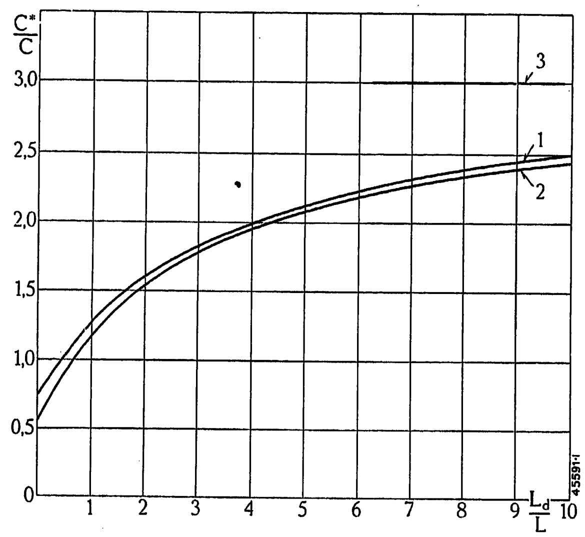


Fig. 19. — Equivalent capacity of the diagram of Fig. 18 in function of $\frac{L_d}{L}$.

1. For the fundamental wave of the natural frequency of the diagram (according to equation 15).
2. Approximation value for big values of $\frac{L_d}{L}$ (according to equation 16).
3. Asymptotes to the curves 1 and 2.

L_d. Inductivity of the choke coils per phase.
L. Leakage inductance of a generator phase.
C. Distributed capacity of a phase of the generator to earth.
C*. Equivalent capacity.

Usually, the three choke coils are distributed uniformly among the three phases, so that there are choke coils on the earthed side of the generator, as well. This arrangement, shown in Fig. 18a, leads to the diagram of Fig. 18b. If, now, the inductivity L_d on the right is, first, left out, this diagram is quite similar to that of Fig. 13a except that the

generator must be considered as a series connection of two lines with different constants. With the help of the equation for long lines, the admittance for the diagram of Fig. 18b is calculated (without inductivity L_d) and the following equation is reached for the natural frequency of this diagram

$$2\,\mathrm{ctg}\,(\omega\sqrt{LC}) - \mathrm{tg}\,(\omega\sqrt{LC}) = 3\,\frac{L_d}{L}\,(\omega\sqrt{LC}) \quad (15)$$

If the natural frequency calculated by this equation is set down as equal to the natural frequency of the equivalent circuit of Fig. 18c (also without L_d), the equivalent capacity C^* is determined. This value is given in curve 1 of Fig. 19.

For high values of L_d/L, equation (15) can be simplified by a series development of the trigonometrical functions (compare Chapter IIIc, especially the way curve 3 is determined in Fig. 15). This allows of determining for the equivalent capacity the approximation value

$$C^* = \frac{9\,L_d + 5\,L}{3\,L_d + 9\,L} \cdot C \quad \ldots . \quad (16)$$

which is shown graphically in curve 2 of Fig. 19. It will be seen that this equation is quite a good approximation even for low values of L_d/L. Therefore, in what follows, equation (16) will be utilized throughout. In the case of the limit value $L_d/L = 0$ the formula coincides with equation (8b). For $L_d/L \to \infty$, C^* is equal to $3\,C$, that is to say the whole distributed capacity is active under the full voltage.

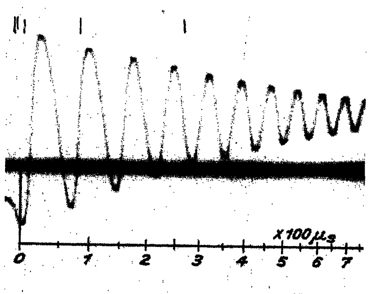
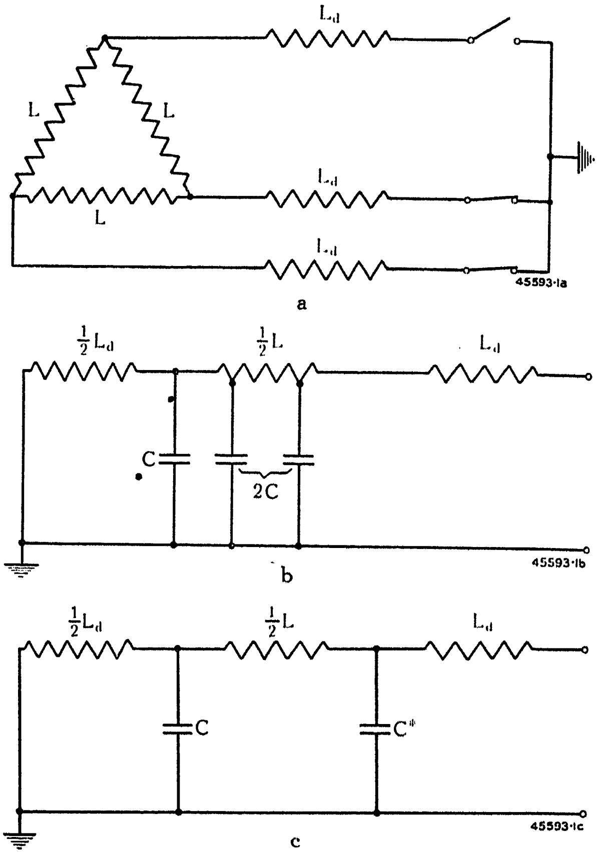


Fig. 20. — Cathode-ray oscillogram of the recovery voltage for the last phases extinguished of a three-phase line to earth short-circuit on the generator of the high-power testing plant, when using the cables up to the test bed and with evenly distributed choke coils on all three phases.
Generator connected in delta.

In the ordinary layout of the high-power testing plant, with three choke coils in series per phase, two natural frequencies are calculated, of 8700 and 21,000 Hz this by using approximated equation (16); these have amplitudes of 85 % and 15 % of the amplitude of the service frequency voltage wave, respectively. The resonance method gives measured values of 9000 and 18,300 Hz.

In the case of the delta connection of the generator winding there is, also, entire symmetry for the last phases extinguished of a three-phase line to earth short-circuit (Fig. 12a). If, as is customary, the choke coils are uniformly distributed on all three phases,



Figs. 21a, b and c. — Diagram and equivalent diagram for the first phase extinguished of a three-phase line to earth short-circuit on the generator of the high-power testing plant, with evenly distributed choke coils on all three phases.
Generator connected in delta.

the symmetry is not destroyed. The equivalent capacity of the generator is, therefore, in this case as well, C/2 for each half of the diagram, as in Fig. 12b. For the usual layout of the plant with three choke coils in series per phase, the natural frequency thus calculated is 14,000 Hz. A second natural frequency has only an amplitude of 0·1 % of that of the fundamental wave, according to calculation. Thus, the oscillation is, practically, a pure sine curve at 14,000 Hz. The calculation is very clearly confirmed by the cathode oscillogram of Fig. 20. The natural frequency measured here being 13,800 Hz. The resonance method gave a measured magnitude of 14,600 Hz.

In the case of the first phase extinguished, a difference must also be made in the case of delta connection, if the choke coils are only inserted on the side which is not earthed or if they are also on the earthed side. In the first case, the same equivalent capacity is valid for the generator as though there were no choke coils connected, at all (compare to Figs. 11a to 11c) because, even when choke coils are inserted, the same points of the generator winding are earthed. When three choke coils are connected on the phase which is not earthed and when the ordinary

cables of the plant are used, the natural frequency calculated is 14,700 Hz. With the resonance method 15,300 Hz is measured.

In the usual connection according to Fig. 21a in which the choke coils are uniformly distributed on the three phases, there is no point of the generator winding at earth potential. The two lower branches with their choke coils can be assimulated to *one* branch with half the inductivity. The lower generator phase acts, here, too as though it were short-circuited but it is active with regard to earth, on account of its capacity. In the case of low frequencies, its whole capacity C can be assumed as being concentrated at its terminals. This leads to diagram Fig. 21b. If the inductivity L_d on the right is assumed to be eliminated, this diagram is the same as that of Fig. 16. An equivalent capacity was found for this connection, with certain assumptions, according to equation (14). In the same manner Fig. 21b leads to

$$C^* = \frac{3\,L_d + L}{3\,L_d + 3\,L} \cdot 2\,C \quad \ldots \quad (17)$$

This value is to be inserted in the equivalent diagram of Fig. 21c.

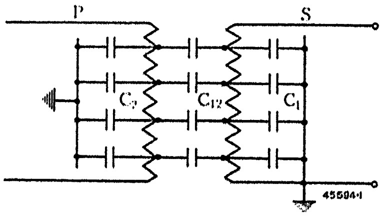


Fig. 22. The capacities which are the deciding ones in the natural frequency oscillations of a transformer.

P. Primary side.
S. Secondary side.
C_1. Distributed capacity of the secondary winding against earth.
C_2. Distributed capacity of the primary winding against earth.
C_{12}. Distributed mutual capacity of the windings.

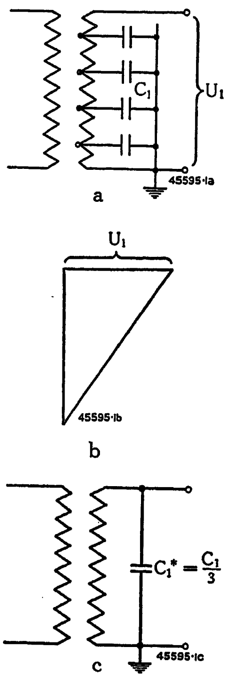
If the choke coils are connected to the generator and breaker through cables, the capacities of the cables have got to be inserted in Fig. 21c. In the case of the high-power testing plant with three choke coils in series per phase, in the usual connection, two natural frequencies are calculated in this way, namely 10,400 Hz and 22,000 Hz, with amplitudes of 87% and 13% respectively. The resonance method leads to measured frequencies of 9800 Hz and 19,400 Hz.

In Chapter VI, it will be again recalled that the behaviour of the oscillations of the recovery voltage is very dependent on the side on which the choke coils are inserted.

IV. THE EQUIVALENT CAPACITIES OF TRANSFORMERS.

(a) *General notes.*

The mutual capacities of different phases of a three-phase transformer can be disregarded as compared with the other partial capacities. On the other hand, the capacities between the different turns of a phase play a much more important part in transformers than in generators. A sudden change in voltage at the terminals of a transformer, therefore, does not pass like a travelling surge through the winding, but there suddenly occurs a distribution of voltage along the winding which depends on the capacities, alone. This, however, is only valid for extremely rapid changes in voltage, i. e. voltage surges with a duration of front of a few μ s, at the most. For frequencies of the order of magnitude of the natural one of the transformer winding or smaller ones, the capacity between the different turns of the same winding plays no great part and can be disregarded, as compared to the capacity to earth of the winding, without affecting too greatly the exactitude of the estimation.



Figs. 23a, b and c. — Determination of the equivalent capacity of the secondary winding for a transformer with one pole earthed.

C_1. Distributed capacity of the secondary winding to earth.
C_1^*. Equivalent capacity for C_1 applied at secondary terminals.
U_1. Secondary terminal voltage.

There are, therefore, still the capacities shown in Fig. 22 to be reckoned with. C_1 is the capacity of the secondary winding to earth, C_2 that of the primary winding to earth. C_{12} is the mutual capacity between the two windings. The designations "primary" and "secondary" correspond to the direction of power flow. The generator is assumed connected on the left side, the breaker to rupture the short circuit being on the right side. In order to calculate the oscillations of the recovery voltage, however, the transformer should be considered from the breaker terminals (from the right). For this reason, the capacity on the breaker side is given the index 1 and the more remote one from it the index 2.

In a transformer, the neighbouring turns of a winding are very closely linked, magnetically. Even at fairly high frequencies, the main flux affects, practically, all the turns of a winding equally strongly. Even in the case of the leakage flux, too, it can be assumed, approximately, that it affects all the turns equally effectively. In any case, this assumption is much closer to the reality than the other extreme one that each field line only affects that turn through which it is generated. When, however, the flux affects all turns equally, independently of the distribution of current among the different turns, the distribution of the potential along the winding will be linear (Fig. 23b).

If each tube of flux only affected the turn producing it, the distribution of potential would still be linear for low frequencies but it would be sine-shaped for the natural frequency, according to Figs. 4b and 4c respectively. If, on the other hand, the flux produced by any one turn affects all turns equally strongly, the potential distribution on the whole range of frequencies is a linear one. The transformer is really between these two limit cases, but the distribution of potential inclines more towards the linear one over the whole frequency range. Even in the first limit case (Figs. 4b and 4c), the equivalent capacity deviates, at natural frequency, only slightly from the equivalent capacity which is valid for linear voltage distribution (compare to curve 1 in Fig. 3). The equivalent capacity in transformers, over the whole range of frequencies considered, coincides all the closer with the value given for the linear distribution of voltage.

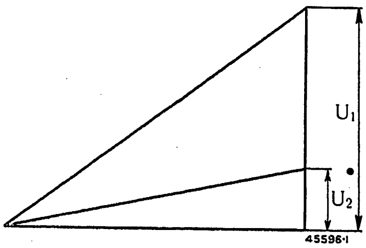


Fig. 24. — Distribution of potential for one phase of the transformer for the case of an earthing of both windings on the same side.

U_1. Secondary terminal voltage.
U_2. Primary terminal voltage.

Now, the three distributed capacities of Fig. 22 have got to be replaced by lumped values. In the secondary winding, i. e. on the breaker side, there is, generally, either one point permanently earthed or else, for reasons of symmetry, it is easy to say which point is at earth potential. In the case of a phase earthed at one end (Fig. 23), an equivalent capacity of

$$C_1^* = C_1/3 \text{ (Fig. 23c)}$$

is found, in the case of linear voltage distribution, by the method of equal energy stored, for example.

For the replacement of the other two capacities in Fig. 22, it is essential to know if one point of the primary winding is, also, earthed or not. If it is a single phase, earthed at one end, the equivalent capacity of the primary winding is given, in quite similar manner to that used for the secondary winding, namely:—

$$C_2^* = C_2/3.$$

This equivalent capacity is to be connected in parallel with the primary winding.

The mutual capacity C_{12}, which represents a shunt to the magnetic linking of the windings, forms the greatest difficulty in estimating the natural frequency. While, otherwise, all load currents in both windings differ according to the ratio of transformation, the mutual capacity makes possible the passage of currents which are of equal strength in both windings. Thus, the usual reduction of inductivities and capacities according to the square of the transformation ratio cannot be applied without modification; here, only the method of calculation with equivalent capacities gives really satisfactory results.

If the primary and the secondary windings are earthed on the same side, the distribution of potential along both windings, for the free oscillation, is that shown in Fig. 24, in principle. Here, U_1 represents the secondary and U_2 the primary terminal voltage. The first is assumed to be higher. However U_2 cannot be deduced from U_1 simply by devision by the transformation ratio; the voltage drop in the short-circuit inductivity of the transformer has to be subtracted. Fundamentally, the whole short-circuited circuit which is ruptured can be represented by the diagram of Fig. 25. Here, L_a is the short-circuit inductivity of the transformer, L_b is that of the generator and lines, C_a and C_b are all capacities on the secondary and primary side of the transformer, respectively, all constants being reduced to the same side. If, now C_b is small as compared to C_a, there is, essentially, only *one* natural frequency and, with it, C_b can be disregarded, the result being quite close enough. The voltage distribution is then purely in relation to the inductivities; thus

$$U_2 = \frac{1}{u} \cdot \frac{L_b}{L_a + L_b} \cdot U_1 \quad \ldots \quad (18)$$

where u represents the ratio of transformation. U_2 becomes zero for $L_b/L_a = 0$, that is to say when the primary side of the transformer is short-circuited, or, practically, when the rated output of the transformer is much smaller than the output of the supply system.

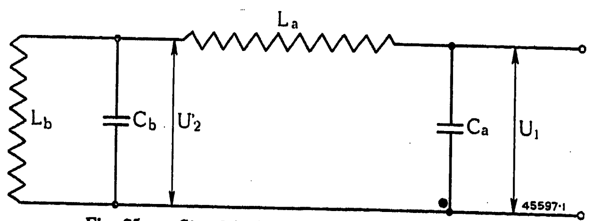


Fig. 25. — Simplified general equivalent diagram.

L_a. Short-circuit inductivity of the transformer.
L_b. Short-circuit inductivity of the generator and conductors.
C_a. All capacities on the secondary side of the transformer (equivalent values for these capacities).
C_b. Ditto on primary side.
U_1. Secondary terminal voltage.
U_2'. Primary voltage reduced to secondary side value.

All values reduced to the same transformer value.

If, on the other hand, C_b is much bigger than C_a, there is a natural oscillation in the circuit (L_a, C_a) for which C_b represents a short circuit. In this case also $U_2 = 0$. It is true that there is also a second oscillation in the circuit (L_b, C_b) in this case, but this latter one is not much influenced by the transformer. It is thus allowable to set down

$$U_2 = 0 \quad \ldots\ldots \quad (18a)$$

when the primary winding is short-circuited or if it is, practically, short-circuited by C_b being big or L_b small. Only if none of these cases occur, then U_2 has to be calculated according to equation (18).

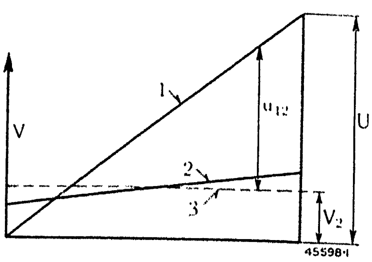


Fig. 26. Potential distribution over the primary and secondary winding of a transformer.

Secondary side earthed on one pole.
Primary side not earthed.
1. Potential of secondary winding.
2. Potential of primary winding.
3. Average potential of primary winding.

Once U_2 has been ascertained, the whole voltage distribution is known, according to Fig. 24. The voltage applied to the mutual capacity C_{12} (Fig. 22) is given by the difference of the two curves of Fig. 24. The equivalent capacity is easily calculated by the method of equal energy stored

$$C_{12}^* = \left(\frac{U_1 - U_2}{U_1}\right)^2 \cdot \frac{C_{12}}{3} \quad \ldots\ldots (19)$$

which has to be connected to the terminals of the secondary winding (parallel to C_1*).

If $U_2 > U_1$ the indices 1 and 2 of equation (19) have to be interchanged and the equivalent capacity connected to the terminals of the secondary winding (parallel to C_2*). This case is very rare, however; it only occurs when the primary winding is on the high-voltage side and when, further, it is neither short-circuited directly, nor through big capacities or small inductivities.

When no point of the primary winding is permanently earthed (Fig. 22), the formulae given for C_2* and C_{12}* are no longer valid. The voltage of the primary winding has to be calculated, now, from the capacitive voltage distribution through C_{12} and C_2. The first case examined is that of the primary winding being at the lower voltage. In this case, the voltage differences along the primary winding are low as compared to the voltage of the secondary winding, and the voltage V_2 along the whole primary winding can be assumed as being constant, with sufficient approximation (replacement of the slightly-inclined straight lines 2 of Fig. 26 by the dotted horizontal straight line 3). C_{12} is under voltage u_{12}, C_2 under V_2. Under the condition that the same current which flows to the primary winding through C_{12} must also flow through C_2 to earth, it is easy to determine the potential of the primary winding, by

$$V_2 = \frac{C_{12}\,U_1}{2\,(C_{12} + C_2)} \quad \ldots\ldots (20)$$

The electric energy stored in C_{12} and C_2 can now be calculated and this gives an equivalent capacity of

$$C_{12}^* = \frac{C_{12}}{3} - \frac{C_{12}^{\,2}}{4\,(C_{12} + C_2)} \quad \ldots (21)$$

C_{12}^* has to be applied to the terminals of the secondary winding and it replaces both C_{12} and C_2.

If there are further external capacities to earth connected on the primary side of the transformer, these must be added to the capacity to earth of the primary winding in the calculation of the potential and of the equivalent capacity. C_2 is considerably increased even by, relatively, short cable lengths. Equation (21) is then simplified to

$$C_{12}^* = \frac{C_{12}}{3} \quad \ldots\ldots\ldots (21\,a)$$

This simpler equation is valid in the great majority of cases. Physically, this is to be understood in the following way:— the average potential of the primary side becomes, practically, zero owing to the bigger capacity to earth, so that C_{12} is between the secondary winding and the earth. When a point of the primary winding is permanently earthed, equation (19), approximately the same value is also obtained as that given by equation (21 a). In the most frequent case, $U_2 \ll U_1$, this equation is exactly the same as equation (21 a).

If the primary winding of the transformer is on the high-voltage side, it is easily understandable that approximately the middle point of the said winding is at earth potential. This is all the truer when additional and symmetrical capacities to earth are connected to the primary winding. As soon as the point of the winding which is at earth potential has been determined, the calculation can be made as in the preceding case treated, in which a point is permanently earthed.

Now, after all the distributed capacities in the diagram of Fig. 22 have been replaced by lumped ones at the terminals of the primary and secondary winding, it is practical to represent the transformer itself, i. e. the winding without capacities by means of the well known Steinmetz equivalent diagram. The no-load inductivity appears, here, as shunt inductivity and can be disregarded in the calculation of short-circuit ruptures. Therefore, there only remains the short-circuit inductivity (compare L_a, Fig. 25) and the equivalent capacities at the terminals. Finally, it should be noted that all inductivities and capacities connected on the primary side (including the equivalent capacity, there, of the transformer itself) have got to be reduced to the secondary side or vice versa. The inductivities connected on the high-voltage side become u^2 times smaller by the reduction to the low-voltage side, while the capacities become u^2 times bigger when u (> 1) is the ratio of transformation.

(b) *Various connections of the transformer.*

In the preceding chapter, the essential data for the calculation of the equivalent capacities, in the case of transformers, were discussed. As, further, the different connections encountered in generators were discussed in detail, it should be clear, without further explanations, how to calculate the equivalent capacities of transformers for the various methods of connection. For this reason, further theoretical discussions are avoided, here, and a comparison is given, in Table I, between calculations and measurements for different transformer connections of the high-voltage testing plant. Of course, no rupturing tests could be made with the transformer alone (without generator). Therefore, all measurements were made by the resonance method. All connections carried out correspond to a three-phase line to earth short-circuit on the high-voltage side; apart from the short-circuit point no other point was earthed on this side. The low-voltage winding was short-circuited across three poles, it being earthed in the first case, then not earthed in the second and, finally, connected to the generator through the ordinary cables, the whole low-voltage circuit being entirely insulated from earth. In all tests, the overhead line of the plant on the high-voltage side was connected up, as no practical rupturing tests can be made unless, at least, this line is connected.

TABLE I.

Phase	Connection	Low-voltage winding earthed		Low-voltage winding not earthed		Low-voltage winding connected to generator
		Natural frequency calculated in Hz	Natural frequency measured in Hz	Natural frequency calculated in Hz	Natural frequency measured in Hz	Natural frequency measured in Hz
first phase extinguished	△‖/⅄S	22,900	21,300	24,800	—	21,200
	⅄‖/⅄S	22,900	22,200	24,800	25,200	22,400
	⅄‖/△S	36,800	36,400	40,000	40,000	36,900
	⅄‖/⅄‖	45,600	44,000	49,500	49,600	44,000
	⅄‖/△‖	73,750	66,800	80,000	73,300	66,900
	⅄S/⅄S	22,900	22,700	24,800	25,200	24,600
	⅄S/△S	36,800	35,400	40,000	38,900	36,200
	⅄S/⅄‖	45,600	42,600	49,500	48,000	43,000
	⅄S/△‖	73,750	67,000	80,000	72,000	67,200
last phases ext.	⅄‖/⅄S	33,600	32,000	33,600	33,200	32,000
	⅄‖/△S	45,000	49,000	45,000	49,000	49,200
	⅄‖/△‖	90,200	90,000	90,200	—	—
	⅄S/△S	45,000	47,700	45,000	48,000	49,000

Calculation and measurement results generally coincide in really satisfactory manner. For the first phase extinguished, the natural frequency ascertained both by calculation and by measurement, with secondary winding not earthed, is somewhat bigger than with earthed secondary, but the difference is, relatively small. When connection is made to the big capacity of the cables and the generator, the natural frequency measured coincides nearly exactly with the value attained with earthed secondary winding, this with a single exception, and differs much more markedly from the value with not earthed secondary winding. In the case of the last phases to be extinguished, the middle point of the low-voltage winding is at earth potential for reasons of symmetry so that the same natural frequency is calculated for winding earthed or not earthed. As a matter of fact, the values measured, in both cases, coincide within the range of measurement precision, and this is also so when the low-voltage winding is connected to the generator.

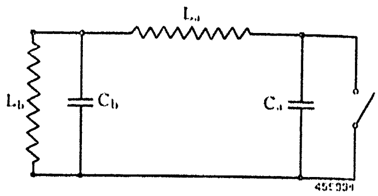


Fig. 27. General equivalent diagram for two natural frequencies without taking the real resistances into account.

V. CALCULATION OF THE OSCILLATIONS FROM THE EQUIVALENT DIAGRAM.

The former chapters showed how lumped capacities applied across the terminals could be made to take the place of distributed ones along the windings of generators and transformers. There now remains to calculate the oscillations for this simplified diagram with its lumped capacities. As it was decided to simplify matters by disregarding damping effects, it is not necessary to take the resistances of the diagram into account. In other words the equivalent diagram only contains lumped inductivities and capacities.

In plants for testing circuit breakers, an equivalent diagram in the form shown in Fig. 27, can always be found to meet the great majority of cases considered and the most important ones. It is a relatively easy matter to calculate the oscillations for this equivalent diagram; for ω^2, the square of the natural pulsation, an equation of the 2nd degree is obtained. For more complicated diagrams equations of the 3rd and higher degrees are valid, the solution of which is complicated and not easy to interpret. While the diagram of Fig. 27 has two natural frequencies, the more complicated diagrams mentioned have three and more natural frequencies. Experience has shown, however, that the stressing of the circuit breaker is sufficiently covered by taking into account the two principal natural frequencies. It is, thus, always recommendable to reduce the plant to an equivalent diagram such as that shown in Fig. 27, even if in so doing it is found necessary to make slight simplifications or to leave out certain factors of little importance.

The Heaviside method allows of calculating the behaviour of the recovery voltage, very simply, in the case of the diagram of Fig. 27; it being assumed that an alternating current is suddenly impressed on the terminals of the circuit breaker, a current which is equal and opposed to the short-circuit current which was first flowing over the breaker. Without going further into the requisite calculations, the result attained is given here. The two natural pulsations

$$\omega_1 = 2\pi f_1 \text{ and } \omega_2 = 2\pi f_2$$

can be calculated from the equations

$$\left.\begin{aligned} \omega_1^2 &= \frac{m}{2} - \sqrt{\left(\frac{m}{2}\right)^2 - n} \\ \omega_2^2 &= \frac{m}{2} + \sqrt{\left(\frac{m}{2}\right)^2 - n} \end{aligned}\right\} \quad \ldots (22)$$

Here

$$\left.\begin{aligned} m &= \frac{1}{L_b C_b} + \frac{1}{L_a}\left(\frac{1}{C_a} + \frac{1}{C_b}\right) \\ n &= \frac{1}{L_a C_a} \cdot \frac{1}{L_b C_b} \end{aligned}\right\} \quad \ldots (23)$$

For numeral calculations it is more advantageous to determine, first, the auxiliary pulsations.

$$\left.\begin{aligned} \omega_a^2 &= \frac{1}{L_a C_a} \\ \omega_b^2 &= \frac{1}{L_b C_b} \\ \omega_c^2 &= \frac{1}{L_a}\left(\frac{1}{C_a} + \frac{1}{C_b}\right) \end{aligned}\right\} \quad \ldots (23a)$$

This allows of substituting for equation (23) the following values:

$$\left.\begin{aligned} m &= \omega_b^2 + \omega_c^2 \\ n &= \omega_a^2 \cdot \omega_b^2 \end{aligned}\right\} \quad \ldots (23b)$$

For the amplitudes A_1 and A_2 of the voltage of both circuit frequencies the result attained, when the square of the service frequency is disregarded as compared to the square of the natural frequency, is

$$\left.\begin{aligned} \frac{A_1}{E_m} &= \frac{\omega_2^2 - \omega_{ab}^2}{\omega_2^2 - \omega_1^2} \\ \frac{A_2}{E_m} &= \frac{\omega_{ab}^2 - \omega_1^2}{\omega_2^2 - \omega_1^2} \end{aligned}\right\} \quad \ldots (24)$$

In the above equation

$$\omega_{ab}^2 = \frac{1}{(L_a + L_b)\, C_a} \quad \ldots (24a)$$

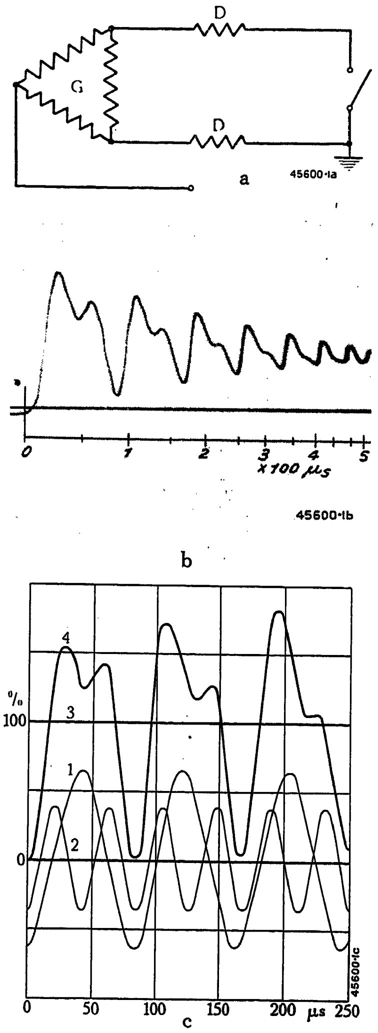
E_m = peak value of the recovery voltage at service frequency. As

$$A_1 + A_2 = E_m \quad \ldots (24b)$$

it is only necessary to calculate the upper equation (24) and A_2 is easier to obtain from equation (24b). If, for example, A_1 is x % of E_m, then A_2 is (100 − x) % of E_m.

The natural frequencies and their amplitudes having been calculated, the oscillations are easy to draw in, because both component oscillations are cos functions which begin with their negative peak values. They are imposed on the service-frequency voltage, which can, usually, be represented as a constant voltage of magnitude E_m in the range of time which is of significance for the characteristic of the oscillations.

Fig. 28 gives an example of this. Fig 28 a represents the diagram of the system of connections being investigated. Only half the parallel cables used under ordinary conditions between the choke coils and the circuit breaker are made use of in this test. Fig. 28 b shows the behaviour of the oscillations of the recovery voltage as recorded by the cathode oscillograph. Fig. 28 c shows the oscillations as calculated. The lines drawn in thin are the two component oscillations of 12,200 and 23,500 Hz with amplitudes of 62·5 and 37·5 % of E_m respectively. The thick curve shows the resultant oscillation curve attained by the combination of the two component oscillations and the stationary value of E_m.



Figs. 28a, b and c. — Composition of the oscillations from the component voltages.

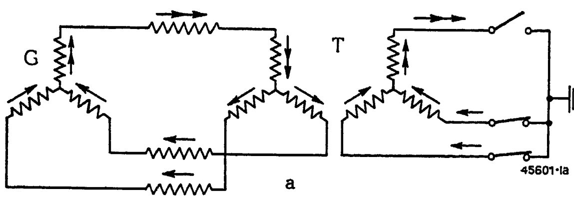
a. Diagram of connections investigated.
D. Choke coil (one coil in the earthed conductor to the breaker and four coils in conductor which is not earthed).
G. Generator.

b. Oscillations as recorded by the cathode-ray oscillograph.

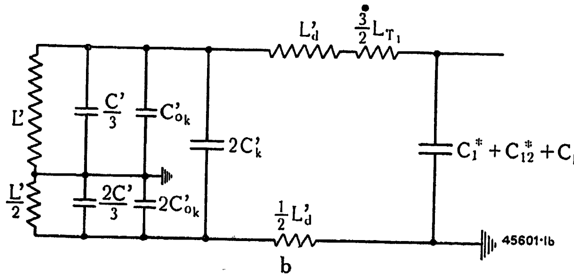
c. Oscillations calculated.
1. Component oscillation with 12,200 Hz.
2. Component oscillation with 23,500 Hz.
3. Voltage at service frequency 50 Hz.
4. Curve composed of 1, 2 and 3.

As these calculated curves do not take damping into account, the later waves are relatively too big. Apart from this, however, in Fig. 28 the curves calculated and those obtained from the oscillograph coincide very accurately. Even the feature that the second boss of the rising wave as compared to the

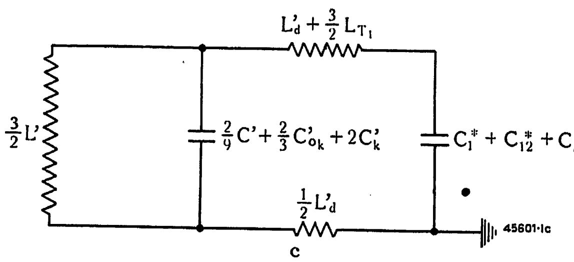
first one gets progressively smaller as time progresses, is faithfully reproduced in the calculated curve. In other cases, where two component oscillations are found with considerably different dampings, the calculated and the measured curves do not coincide so well for so many cycles. The character of the resultant curve is modified by the various damping of the component oscillations, so that it deviates in later cycles from the calculated curve which does not take damping into account. However, the behaviour of the oscillations for ulterior cycles is without influence on the behaviour of the circuit breaker. In this respect, the only factor of interest is the character of the oscil-



a



b



c

Figs. 29a, b and c. — Composition of the equivalent diagram for a complete system of connections of the plant.

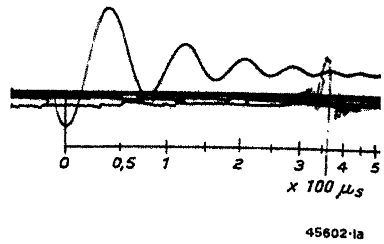
a. Diagram of connections. b. Intermediate diagram. c. Equivalent diagram.

lation up to the first peak or, possibly, up to the second one, if the latter is higher. In this range, the behaviour of the oscillations is reproduced quite faithfully enough without taking damping into account. This is always under the assumption, however, that the recovery voltage is determined during rupturing by means of an ideal circuit breaker[1].

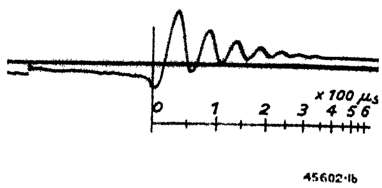
VI. EXAMPLES OF COMPLEX SYSTEMS OF CONNECTIONS.

The preceding chapters give the requisite basis for calculating the oscillations of the recovery voltage, in the case of a complex system of connections. Even in complicated connections, the first thing to be determined is what the points are which are at earth potential. As soon as this is known, the lumped equivalent capacities for the capacities distributed along the windings can be ascertained relatively easily. After this, the natural frequencies and the amplitudes inherent thereto can be calculated from the equations which were given in Chapter V.

The detailed calculation will only be made for a single example, namely the case of the high-power testing plant with generator star-connected, transformer star/star-connected and with choke coils inserted on all 3 phases. For the first phase to be extinguished, in the case of a three-phase line to earth short-circuit, the diagram of Fig. 29a is valid. On the high-voltage side (right) a point is permanently earthed, so that the distribution of potential is seen immediately.



a



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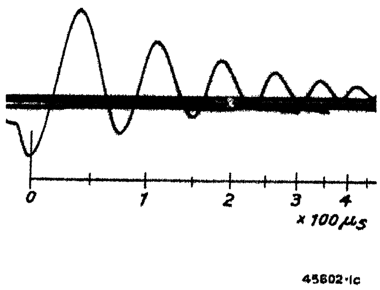


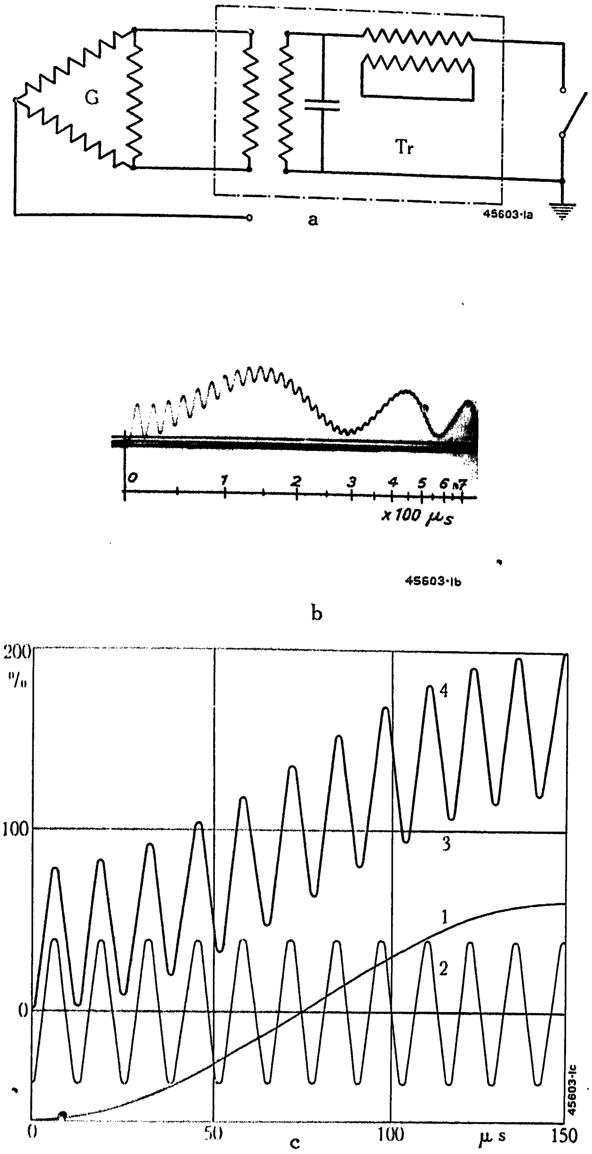
c

Figs. 30a, b and c. — Cathode-ray oscillogram of the recovery voltage with star connection of generator and transformer, and for three-phase line to earth short-circuit.

a. For the phase extinguished with a transformer ratio of four and using three choke coils per phase.
b. Ditto without choke coils.
c. As in a but for the last phases extinguished.

On the low voltage side, it will be seen that the neutral point of the generator and transformer is constantly at earth potential under the oscillation which is represented by arrows in the diagram. In the generator and the transformer, the two lower phases, here, have opposite and, in the average, half as big potential as the upper phase. As the capacity to earth of both phases is together twice as big as that of the upper phase, exactly the same capacity current flows from them to earth as flows back from earth to the upper phase. The same reasoning can be applied to the capacity to earth of the cables which connect the generator with the choke coils. When the

[1] See remark in foot note on page 283.



Figs. 31 a, b and c. Arrangement to allow of attaining higher natural frequencies.

a. Diagram of connections.
b. Cathode-ray oscillogram for a.
c. Oscillations as calculated.

1. Component oscillation at 3300 Hz.
2. Component oscillation at 75,000 Hz.
3. Voltage at service frequency 50 Hz.
4. Curve made up of 1, 2 and 3.

neutral points are at earth potential, there is, thus, no resulting capacity current flowing to earth; or, conversely, as no resultant capacity current can flow to earth, the neutral points always remain at earth potential.

In reality, a resultant current does flow from the low-voltage side to earth, and it is of the magnitude of the capacity current from the high- to the low-voltage winding of the transformer. As, however, the mutual capacity of the two transformer windings is much smaller than the earth capacity of generator and cables, the latter are, practically, alone in determining the potential situation of the low-voltage winding.

It having been shown that the neutral point of the generator is permanently at earth potential, the distributed capacity C of each generator phase can be replaced by a lumped capacity of the magnitude of C/3 applied between terminals and neutral point. In this way the diagram of Fig. 29 b is formed, which replaces that of Fig. 29 a. Here, the transformer is, also, replaced by its short-circuit inductivity (L_{T1} per phase). The inductivities and capacities connected on the low-voltage side must be reduced according to the ratio of transformation (for this reason, all these magnitudes are provided with a sign′).

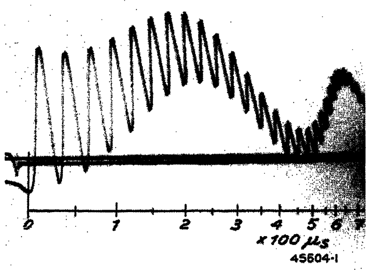


Fig. 32. — Cathode-ray oscillogram with two natural frequencies of considerable component amplitudes.

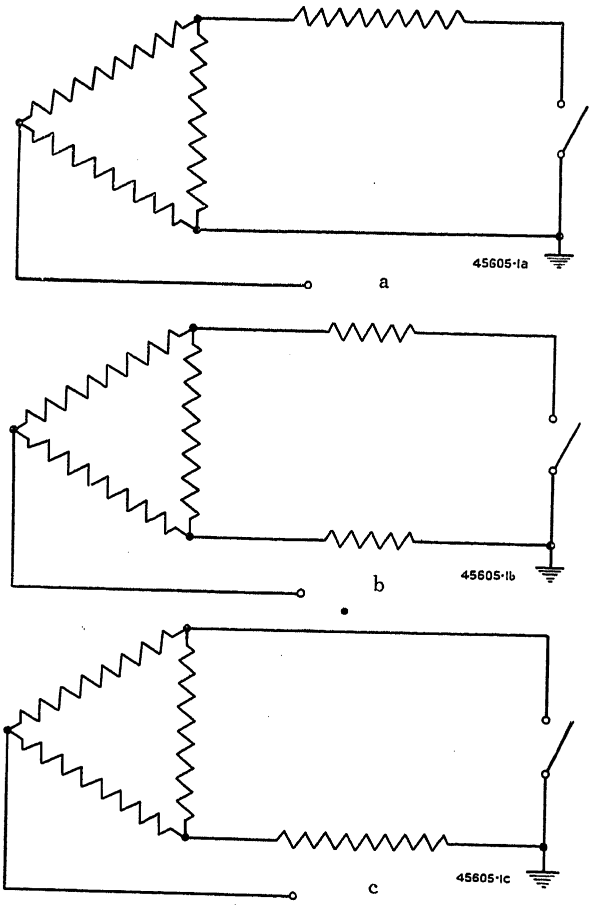
There are two capacitive branches connected in parallel to the inductivity of the generator winding $\left(L' + \frac{L'}{2}\right)$; these are connected to the inductive branch at the neutral point. As the proportion of the impedances is the same for all three branches before and after the neutral point, the points connected are also at the same voltage under an alternating current flowing as shown by the arrows in Fig. 29b, even if the connection is broken. It is, therefore, allowable to consider the connection as non existent and this allows of deducing Fig. 29c from Fig. 29b. This figure coincides with the simple diagram of Fig. 27, because the inductivity $^1/_2\, L'_d$ of the lower branch can be displaced to the upper branch (in series with L'_d) without this modifying the impedance of the diagram.

As numeral example, three cases with Y||/Y|| connection of the transformer were calculated. For the first two cases, the recovery voltage after the extinction of the first phase was calculated and this, once, when using three choke coils per phase and, once, without choke coils. In the third case, the recovery voltage was calculated after the last phases extinguished, with the insertion of three choke coils per phase. The cathode oscillograms recorded are reproduced in Figs. 30a—30c. In all three cases, the characteristic of the recovery voltage is practically a sine curve. The natural frequencies extracted from the oscillograms are reproduced, along with the values calculated, in Table II. Further the values reached by the resonance

TABLE II.

Natural frequencies in Hz for three ordinary connections of the high-power testing plant.

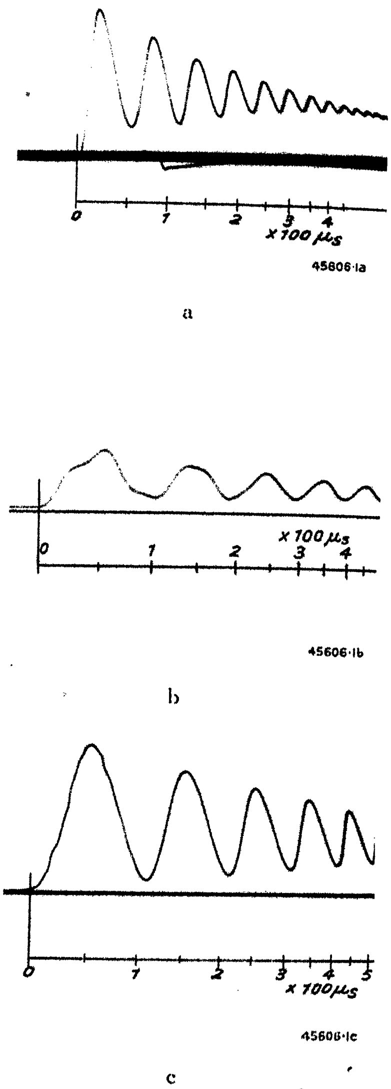
Connections as in figures	30 a	30 b	30 c
Values extracted from the cathode-ray oscillograms	12,200	19,100	13,200
Values measured by the resonance method . . .	12,400	18,900	14,000
Values calculated	12,100	18,700	17,300



Figs. 33a, b and c. — Layout with different distribution of the choke coils in the circuit.

Fig. 31 b shows the characteristic of the recovery voltage as recorded by the oscillograph. The curve is made up of two oscillations; one has a low frequency and the other a very high one and a considerable amplitude, as well. By suitable choice of the constants of the circuit, it is possible to attain that the amplitude of the high frequency relatively to that of the lower one, is made still greater (compare to Fig. 32).

The oscillogram of Fig. 31b was analysed and the results are shown in Table III. For the purpose of comparison the calculated values of the natural frequencies and amplitudes are also given.



Figs. 34a, b and c. — The cathode ray-oscillograms for the layout shown in Fig. 33.

method are also given. The calculation carried out according to the diagrams treated in the preceding chapter gives a second frequency which is greater, but its amplitude, in the three cases, is only 0·5, 2·8 and 2·5% respectively. The calculation thus confirms that the oscillations of the recovery voltage are, practically, purely sine curves.

In ordinary systems of connection such as that just treated, the natural frequencies can be lowered by connecting condensers in parallel with the circuit-breaker terminals. On the other hand, an increase of the natural frequency cannot be attained by such simple means. It is, however, possible to attain a much faster voltage rise by certain artifices. A system of connections allowing of this is shown in Fig. 31a. The generator operates on two phases of the transformer while the third phase is connected as a choke coil to the high-voltage side.

TABLE III.

	Natural frequency in Hz		Amplitude in %	
	measured	calculated	measured	calculated
Low frequency .	3,500	3,300	66	61
High frequency .	67,000	75,000	34	39

The approximation of values calculated and those measured is very satisfactory. The resultant oscillation composed of the composite oscillations calculated is shown in Fig. 31c. Apart from the damping, the curve calculated approximates closely to the curve given by the oscillograph.

To conclude, an example is given to show how much the behaviour of the recovery voltage depends on where the choke coils are inserted. In all three connections of Figs. 33a to 33c exactly the same elements are made use of, but the two choke coils are placed, once, on the not-earthed side, once, on the earthed side and, once, on both sides. The oscillograms of Figs. 34a to 34c show the respective characteristic of the recovery voltage. In the first case, this is a pure sine curve, in the second case, a second frequency appears and in the third case the characteristic is, again, practically, a pure sine curve but at a considerably lower frequency.

(MS 575) *Dr. W. Wanger, J. K. Brown. (Mo.)*

THE COSSONAY SUBSTATION (SWITZERLAND) EQUIPPED WITH AIR-BLAST, HIGH-SPEED CIRCUIT-BREAKERS.

Decimal index 621. 316. 267 (444).

THE switchgear linking the Cossonay cable works (Câbleries de Cossonay) to the network of the Cie Vaudoise des Forces Motrices des Lacs de Joux et de l'Orbe had to be transformed as a result of the installation in the said Câbleries de Cossonay of a Brown Boveri electric boiler of 4000 kW and of electric furnaces. The new substation was designed for an incoming, overhead transmission line at 38 kV from the Montcherand substation and two other incoming, overhead lines which form the links to the "Osmon" and "Sullens" lines belonging to the Forces de Joux. The electric boiler [1] as well as the transformers of the works are supplied at 13 kV.

The layout adopted comprises two transformers of 2800 kVA, each, with a voltage ratio of 38/13 kV, to allow of supplying the boiler from the 38-kV line, the other power requirements of the works being supplied by either the "Osmon" or the "Sullens" line; a parallel working of the 38-kV and 13-kV systems is also feasible. Fig. 1 shows the fundamental diagram of connections of the station.

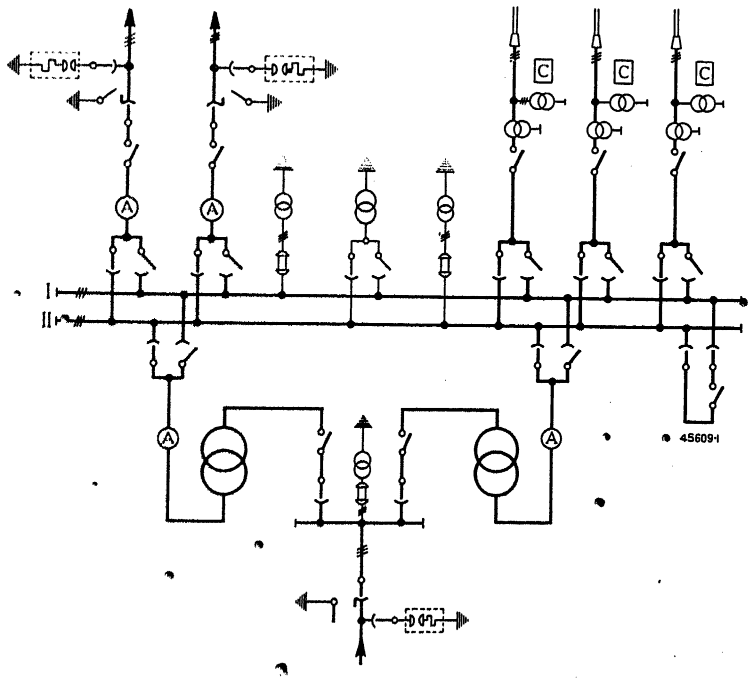


Fig. 1. — Fundamental diagram of the Cossonay substation.

A first scheme for this substation had assumed the utilization of oil circuit breakers. Although the oil circuit breaker is a very reliable apparatus, to-day, on condition that its design be based on thorough preliminary investigations carried out in a high-power testing plant, there is always the possibility of disastrous consequences resulting from some accident due to faulty remounting after overhaul work. However perfect the oil circuit breaker may be, it must always be isolated in a cell with a pit for collecting oil and a duct for carrying it away. All the space below the circuit breaker is, thus, lost as far as the layout of the connections and certain apparatus is concerned. In the present case, the circuit breakers, 38 kV, would have been lodged on the ground floor and the 13-kV circuit breakers on the first floor, which is divided into two parts by a partition carrying the bus-bars. Fig. 2a shows a section of the building as it was designed for equipping with oil circuit breakers.

Due to the considerable progress made in the development of circuit breakers without oil, in the course of recent years, the Cie Vaudoise des Forces Motrices des Lacs de Joux et de l'Orbe decided to work out an alternative plan for the substation, utilizing air-blast, high-speed circuit breakers. A description of the air-blast, high-speed circuit breaker has already been given in The Brown Boveri Review [1], but it will not be out of place to recall, here, a few of the chief features of this breaker which have special significance for the mounting of same. The features in question open up new possibilities as regards the layout of plants in which these breakers are installed.

There is not a trace of oil in the Brown Boveri air-blast, high-speed circuit breaker, even in a damping device; thus, the breaker contains no element which might cause fire. The pressure in the extinction chamber is the same whether the rupture is under full load or under no load; this pressure is generated in the compressor and it is limited by the safety valves of the compressed-air distributing system and, thus, cannot be exceeded:— there is no danger of an explosion. Every part of the breaker can work in any position; thus, the breaker can be mounted vertically, horizontally or, even, suspended from the roof. Thus, quite new possibilities are opened up by the facility offered of being able to make the connections according

[1] See The Brown Boveri Review of September 1937.

[1] See The Brown Boveri Review of November 1935.

to the simplest and most advantageous layout, the breaker being then mounted in whatever position is most convenient to the general scheme. Every suppression of looped conductors, of parallel circuits and reduction of the length of circuits increases the resistance strength of a plant as regards electro-dynamic stressing. Finally, attention should be drawn to the fact that the Brown Boveri air-blast, high-speed circuit breaker can be overhauled with great facility. The loosening of four bolts, without removing any connections at all, allows of inspecting all the parts making up the extinction chamber. In other words, it is, practically, never necessary to withdraw the breaker from its cell. As regards the exposed disconnecting link in air, it is always visible to inspection and is only subjected to very slight mechanical wear due to friction. The fact of there being a knife-type switch on the breaker always visible to an operator contributes largely to make safer the operation of the disconnecting links of the plant.

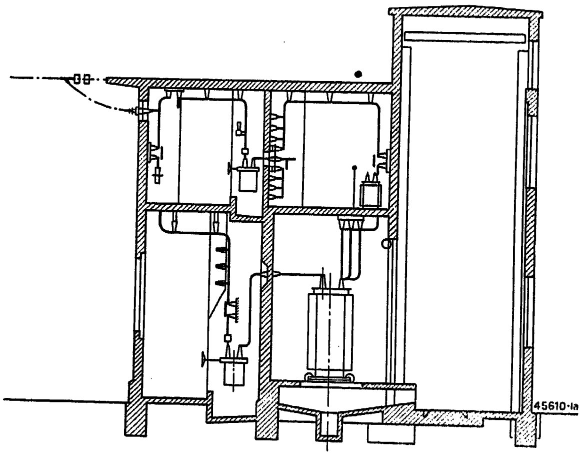


Fig. 2a. — **Section of substation equipped with oil circuit breakers.**

It is obvious that the use of Brown Boveri air-blast, circuit breakers allows of a departure from former switchgear layouts and permits of considerably simpler installations. The alternative plan with air-blast, circuit breakers studied for the Cossonay station was based on the hall type of plant. All the 13- and 38-kV gear was lodged in a single rectangular chamber; the two cells to hold the 2800-kVA transformers are located along one of the longer sides, the two cells being separated from the switchgear by a wall. Between the cells an erection tour has been provided and this is also used to anchor the overhead lines. Fig. 2b shows the layout. A comparison with Fig. 2a shows, at once, that the new building must be much cheaper than the former one. With about the same floor area, it has been found feasible to eliminate one floor, while leaving room for a spare outgoing line. All the concrete partitions and the ducts for carrying off oil have been done away with. As the air-blast circuit breakers cause no external mechanical reaction to speak of, as compared to the shock produced on the cover of an oil-immersed circuit breaker, the iron anchoring parts can be made lighter. The different circuits stand out as clearly as in a diagram of connections which facilitates supervision and overhaulage work.

These different advantages, both economical and technical, were the reason for the choice being made in favour of compressed air for the breakers.

The simplest layout of the leads was attained by placing the two 38-kV circuit breakers horizontally, that is with the six terminals on the top side. Connection between the circuit breakers and the 38-kV terminals of the transformers is by exposed bars. On the contrary, the 13-kV terminals of the transformers are connected by cables to the two sets of "Osmon" and "Sullens" bus-bars. As regards the outgoing 13-kV cables, it is, obviously, the vertical position of the circuit breaker with three terminals above and three below which is the most convenient one (Fig. 3). In this case, it is very advantageous to insert a plate of sheet metal between the insulators and the compressed-air container, which then separates entirely

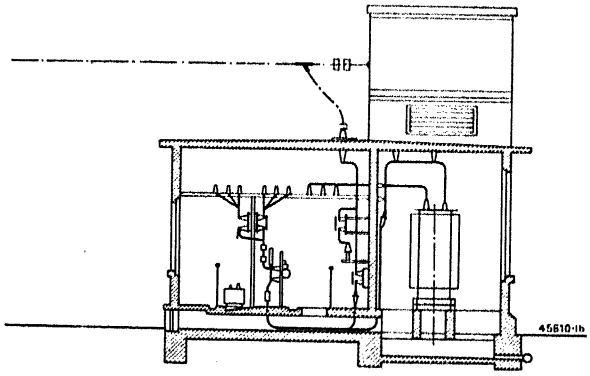


Fig. 2b. — **Section of substation equipped with air-blast, high-speed circuit breakers.**

those parts which are under voltage from the other elements of the apparatus. The electro-pneumatic valves can, thus, be reached without any danger while the apparatus is under voltage. All the organs of control can be supervised on site, very easily. In the case of horizontal mounting, as was carried out for the 38-kV circuit breakers, it would be dangerous to manipulate the control valves by hand the clearances from parts under voltage being insufficient. For this reason a mechanical control by metal cable is made use of with two little handles mounted in front of the protection grid and by means of which the valves can be safely controlled.

The 13-kV and 38-kV circuit breakers have primary relays of Type HB 4 which can be adjusted for 1 to 2 times the rated current and for 0·3 to 6 seconds. The high precision which characterizes these relays combined with the rapid action of the Brown Boveri air-blast, high-speed circuit breakers allows of setting the time-lag graduation from relay to relay in branched systems much more closely than would have been possible some years ago. These relays act mechanically on the governing valve for tripping the breaker.

Brown Boveri Resorbit lightning arrestors are installed at the entrance of the 13- and 38-kV lines (Fig. 4). The absorption capacity of these arrestors and the very low residual voltage protect the plant most efficaceously against atmospheric excess voltages.

It is obvious that ordinary high-voltage fuses which generate a great deal of gas at fusing can, no longer, be put into a plant of this kind, as the said gas is liable to produce arcing across the bus-bars. The fuses used at Cossonay (Fig. 5) are of a new type, of high-rupturing capacity and acting without any external manifestation. They act so quickly that the current does not have time to build up to its peak value at all; the result is efficient protection against electro-dynamic effects of the short-circuit current. If the fuse blows, a red button appears at the lower end of the fuse, showing, clearly, that the

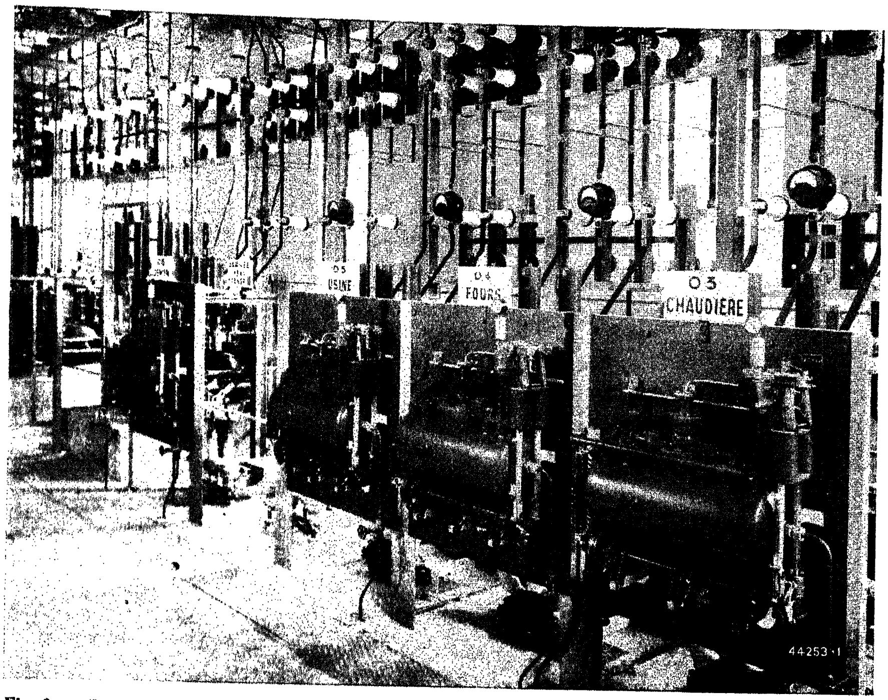


Fig. 3. — Partial view of the air-blast, high-speed circuit breakers Type D 11 i 100 with sheet metal plate for erection. 13-kV side of substation. In the back-ground: — breakers of Type D 37 i 500, on the 38-kV side.

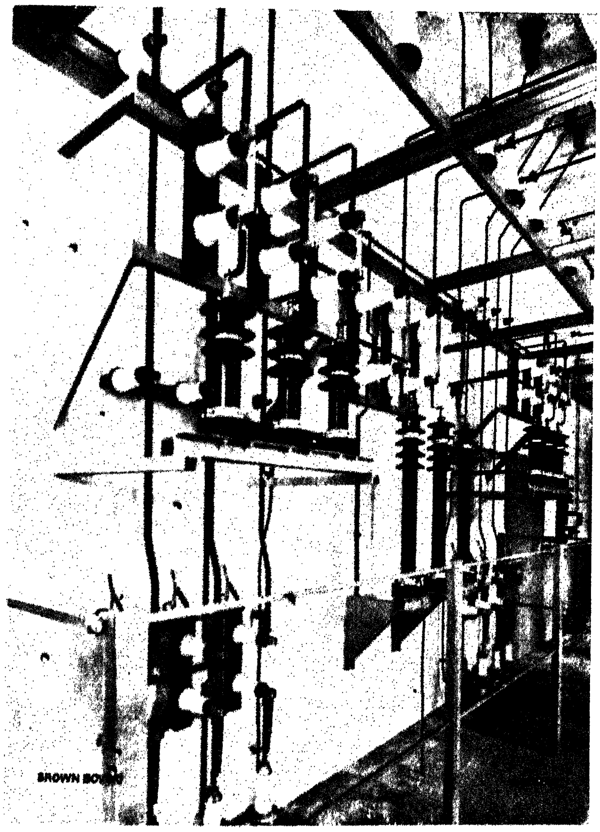


Fig. 4. — Resorbit lightning arrestors placed at the entry of the overhead lines to the substation.

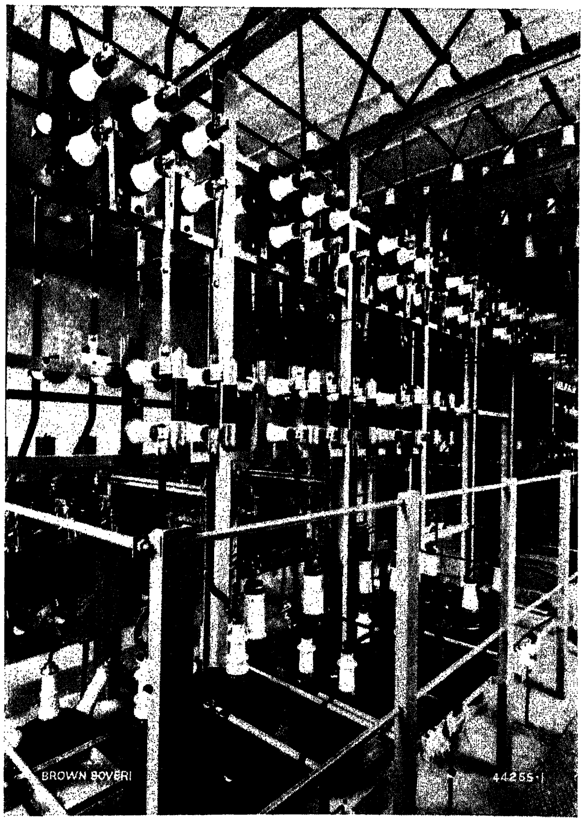


Fig. 5. — High-capacity fuses Type C 11 and rear view of air-blast, high-speed circuit breakers.

apparatus has acted. Fuses of this type were used for the voltage transformers, the earthing coils and for the transformer supplying auxiliary requirements and which is, now, for 11 kVA and will, later, be for 50 kVA. One of the great advantage of the Brown Boveri high-capacity fuses is that they can be repaired by the service operators, themselves, this makes them very cheap to use in service.

Many station authorities do not care for the idea of requiring compressed air for operating the breakers, they fear that it may be the cause of trouble and that il will be a weak point in their plant. It is quite true that it is indispensable that the supply of compressed air to the breakers be absolutely assured, but, to-day, all the elements necessary for making the plant absolutely air-tight are available. With the present design of compressors, it can be asserted that compressed air, as an auxiliary source, is, at least, as reliable as is a storage battery to electrical supply. It is preferable to make the piping of copper and the branches are provided with intermediate copper joint pieces which give a perfect sealing by compression. An accumulator tank is inserted between the compressor and the circuit-breakers the pressure in which is superior, if possible, to the service pressure and which has a throttling valve. This forms a considerable reserve under a restricted volume. It is, also, possible to put in several of these accumulators at different points of the plant, instead of one, only. The total spare capacity is calculated to allow of a certain number of operations in the range between the limit pressure at which the compressor set should have started and the limit pressure at which the breakers are locked. The number of these operations varies from one plant to another, according to service conditions and to the number of breakers installed. It is not necessary to exagerate the size of this compressed-air reserve because it is always possible to renew the tank charge by means of a compressed-air container, during a necessary overhaul of the compressor. According to the size of the plant, a ring layout of the piping may be adopted allowing of putting certain elements out of service.

In the Cossonay station, the compressor works between 12·5 and 14·5 kg/cm². The air is injected into a tank of 1000 litres capacity. The two 38-kV circuit breakers are supplied straight from this tank. The supply pipe of the 13-kV circuit breakers is branched on the main tank through a throttle valve 14/8 kg/cm². At the end of the pipe 8 kg/cm², there is a 300-litre tank. If, for any reason, the compressor set does not start when the pressure falls to 12·5 kg/cm², an acoustical signal calls attention of the watchman to this state of things. This alarm also works in the case of excessively high temperatures occurring in the transformers. The watchman has then got to go to the substation in which optical signalling devices show him what kind of trouble has arisen. In the case of the compressor set not working, without there being a loss of air on the compressed-air system, immediate intervention is not essential; the storage is sufficient to justify the watchman in, simply, informing the proper authorities of what has happened. He will stop the acoustical alarm, while the optical signal remains in the "alarm" position (red disc); only going back to its ordinary position "normal service" (white disc) after the plant has been put in order. Thus, warning is given of faulty operation of the compressor while there is still sufficient air storage in hand to allow of several manipulations being carried out on the circuit breakers. Thus, there is ample time for the carrying out of the overhauling work called for.

Ammeters are inserted, straight, on the 13-kV lines; they are mounted on insulator supports. The meters on the outgoing lines, as well as the voltmeters at 38 and 13 kV, are on a small panel near the entrance. The optical signalling apparatus, already mentioned, are, also, countersunk in this panel.

Thus, the Brown Boveri air-blast, high-speed circuit breaker has allowed of building a plant which is simple, safe and cheap. It must be noted, however, that when a plant like this is planned, or any other circuit-breaker installation, it would be wrong to limit the comparison to the respective prices of oil-immersed and air-blast circuit breakers. If it is decided to put in air-blast circuit breakers, full advantage should be taken of all the real qualities they possess and the station should be laid out with this in view. It will then be perceived that the comparison is decidedly in favour of the air-blast circuit breaker.

(MS 573) *H. Gavin. (Mo.)*

NOTES.

Single-phase A. C. motor coaches of the Norwegian State Railways.

Decimal index 621.335.4 (481).

THE Brown Boveri Review already commented on the development of motor-coach traffic on the Norwegian State Railways and on the coaches used for this purpose.[1]

Since the last article on the subject was published, the three motor coaches mentioned therein, for the Voss-Eide line section, have been put into service. These were followed by four others, used, chiefly, on the Oslo-Ski suburban line section, while there are six further motor coaches building which are, also, intended for work on Oslo suburban lines.

All these motor coaches are full-gauge vehicles, for single-phase A. C. current supply, at 15,000 V and $16^2/_3$ Hz. The design aims at weight saving, this although no pronouncedly light coach model can be used here, on account of the service conditions encountered (runs with trailers in mountainous country or heavy suburban traffic conditions). Further, all the coaches have the same type of driving motors of which there are four

[1] The Brown Boveri Review of November 1931 and August 1934.

per coach. These are series-wound, self-ventilated motors of the usual nose-suspended type and having big gear wheels of the resilient type. The one-hour rating of each motor is 116 kW at 1160 r. p. m.; the continuous rating is 95 kW at 1330 r. p. m., measured on the motor shaft. The two motors of each bogie are constantly connected in series with one another. In the case of the Voss-Eide line section, with its steep grades and the maximum speed of 50 km/h here specified, the ratio of the reduction gear is 1 : 5·54 and it is 1 : 4·27 in the other coaches which attain 70 km/h travelling speed. The diameter of the driving wheels, when new, is 810 mm, in every case.

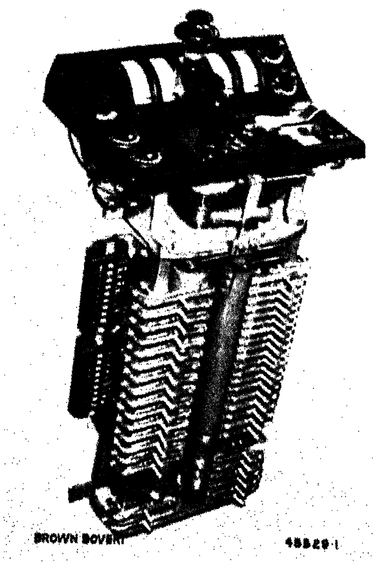


Fig. 1. Motor coach for the Voss-Eide line section. Master controller and braking controller combined in one apparatus.

This driving-motor equipment allows of running on the steepest grade, which attains 45 ‰ on the Voss-Eide line section, at a speed of 32 km/h, with a contact-wire voltage of 15,000 V and a total train weight of 106 t. In suburban-line traffic in Oslo, however, the maximum total weight of a train per motor coach attains 120 t. The weight of the motor coach empty is 35·5 t on the Voss-Eide section and, on the Oslo suburban lines, about 41·76 t. Although the electric equipments of both the motor-coach types coincide as regards the driving motors, there are, nevertheless, considerable differences between them. The Voss-Eide motor coaches, like those delivered earlier, are equipped with A. C.-supplied electromagnetic contactor control, A. C. lighting installations, separate electric radiators and with an electric braking equipment. This last equipment is not provided for the motor coaches for Oslo suburban service. The latter have, as an innovation, control by cam-type controllers, D. C. lighting and electric air-heating devices.

The electric braking of the Voss-Eide motor coaches has some interesting features; thanks to it, it is possible to hold the trains running down the long, steep grades at constant speed without having to fear loosening of the wheel tires, further, the well-known advantages in saving on upkeep and replacements of wheel tires and brake shoes are gained. Traffic on this line section is fairly light and can, frequently, be taken care of by motor-coaches running alone without trailers; this, and the necessity of not exceeding a determined weight of coach, caused the NSR to call for electric braking of the motor coaches only, which are the seat of the greatest wear in any case, and not for that of the trailers. A relatively moderate braking power only is called for in order to maintain at constant speed the motor coach weight running down the 45 ‰ grade. The adhesion load on three axles is amply sufficient to produce the braking power in question. Therefore, and in conformity with a system of connections thoroughly tried out earlier by Brown Boveri[1], only three driving motors are used for braking and these are excited by the fourth one, which thus, does some braking work, as well. This fourth motor is, itself, excited in close regulation steps, from the generator of a small braking converter set. Independence from the contact wire is not attempted, for the sake of simplicity.

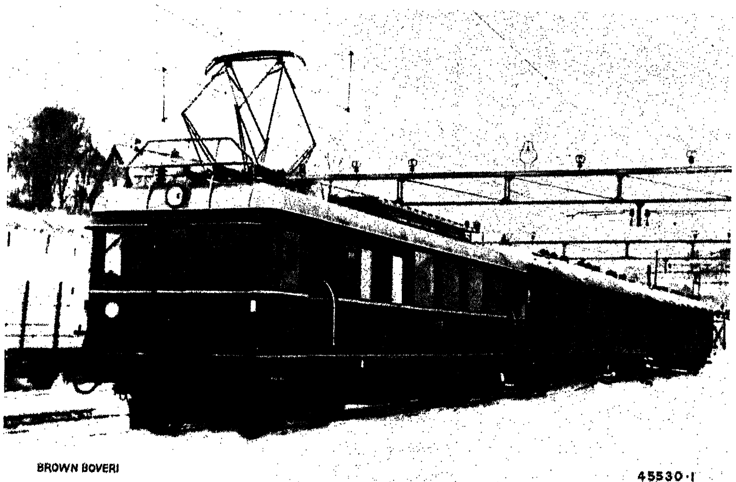


Fig. 2. — Train unit in the Voss station.

This equipment is used, as said before, for braking on down grades. Therefore, if was unnecessary to lower the speed range for braking to the neighbourhood of stopping, which, with this connection, would have meant a relatively too big con-

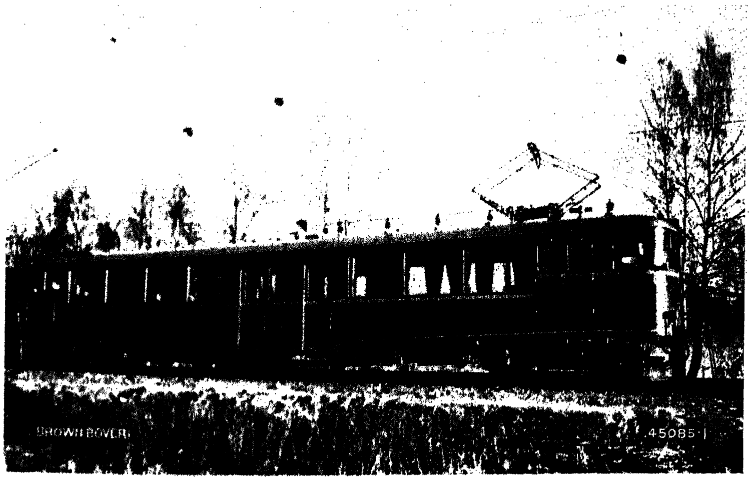


Fig. 3. — Motor coach for the Oslo-Ski suburban line section.

[1] The Brown Boveri Review of May/June 1932.

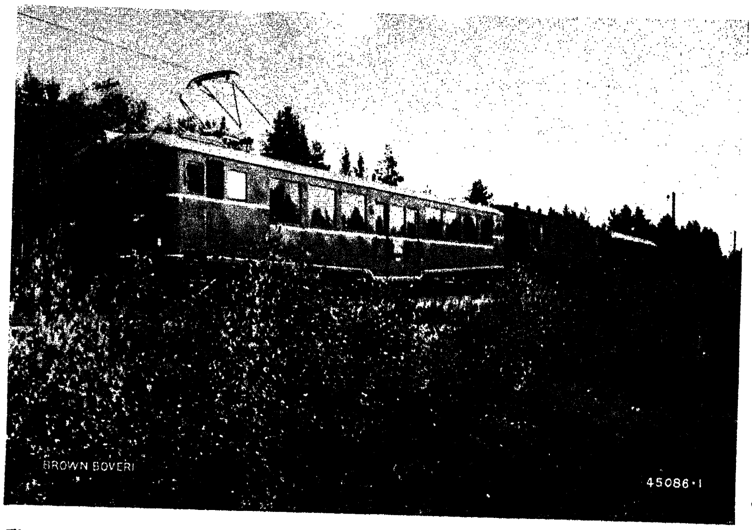


Fig. 4. — Motor coach for the Oslo-Ski line section with trailers, on a trial run on the Oslo-Drammen line section.

sumption of excitation. Therefore, the lowest braking speed was fixed at 20 km/h while the highest speed is 50 km/h, this being the maximum allowed for the motor coaches.

There is a special drum in each diver's stand for adjusting the braking excitation, this drum being combined with the driving controller. Fig. 1 shows a controller of this type. The main drum on the left controls the contactors, the braking drum being on the right. On the right and below is located the control drum for the travel reverser and for braking change over.

Experience in service has confirmed the excellent characteristics of this braking arrangement which had been noted on trial runs; its smooth, flexible operation, both when braking is applied as well as when travelling speed is changed, is a very pleasing feature.

While on the subject of the Voss-Eide motor coaches, it may be added that the transformer is of the usual design, oil-immersed with cooling pockets and is suspended below the coach body. Its continuous rating is 375 kVA for supplying the driving motors, while there are 25 kVA to be provided for auxiliary services and 60 kW for heating, as well.

The electro-magnetic contactor control is of the multiple unit type, it has nine running positions. The trains have continuous vacuum brake equipment; there is a vacuum pump on each coach to provide the requisite vacuum, this pump being driven by a single-phase series-wound motor. A second auxiliary motor of the same design drives a small compressor which gives the necessary compressed air to actuate the current collector, the reverser and the braking change-over switch as well as the whistle and sand sprayer. These motor coaches are heated by ordinary radiators connected up to a tap on the tapping transformer at about 1000 V. A small transformer, the high-voltage winding of which is connected to the same tap, lowers the voltage to that required for lighting at $16\,^2/_3$ Hz, namely to only 12 V. In the case of the contact-wire voltage failing, the emergency lighting equipment comes into action, which is supplied by a storage battery charged from an external source.

Fig. 2 shows a train in the Voss station. This illustration dates from the time tests were being made before the official opening of service.

In the case of the motor coaches for the *Oslo suburban traffic*, the transformer carries about the same load as the driving motors (because there is no electric braking). Its output had to be 458 kVA for the supply of the driving motors to which must be added 30 kVA for auxiliary purposes and 90 kW for coach heating. The design and method of suspension of the transformer is the same as on the Voss-Eide motor coaches.

In order to attain entire service reliability despite the considerable voltage fluctuations occurring on suburban service, a cam-type of controller also for multiple-unit control was chosen here, the number of running steps being increased to 10. The cam shaft of the controller is rotated through the agency of a driving apparatus controlled by electric motor. The control current is D.C. at 32 V, average voltage. The current for lighting the train comes from the same source, which is a train-lighting generator and a storage battery connected in parallel with it. The generator in question is driven from one of the axles of the coach through a gear and a cardan coupling.

As compared to the earlier motor coaches, innovations have been introduced to the heating equipment, apart from those of the control and lighting equipment. Thus, the electric air heating system developed during recent years has been applied here. Up to 30 kW is transformed into heat in a heating resistance suspended under the coach floor and this heat is transmitted to a current of air driven by a fan which delivers it to the different compartments.

The power used for heating can be reduced progressively, in steps down to 2·5 kW, when the external temperature is mild. In all cases, the fan runs continually and, thus assures a more regular renewal of air than would be the case if the heating were turned full on and then suddenly turned off in rapid succession by the action of a thermostat.

In summer, the same equipment is utilized, after cutting out the heating resistance, for the cooling of the coach. The available quantity of air amounting to 20 m³/min suffices to make travelling in the coach pleasant, even on the hottest summer days.

These coaches are braked by compressed air delivered by a motor-compressor set, Type EZB 3, delivering 700 l/min against a head of 6 kg/cm² gauge.

Figs. 3 and 4 give service records taken on the motor coaches of the Oslo suburban lines.

While the electric equipments of all the motor coaches in question were, or will, be built by A/S Norsk Electrisk & Brown Boveri in Oslo, the mechanical parts of the Voss-Eide motor coaches were delivered by A/S Strömmens Vaerksted of Oslo and those of the coaches for Oslo suburban lines by A/S Skabo Jerbanevognfabrik in Sköyen near Oslo.

For the suburban traffic train units are formed, composed of a motor coach, an interconnecting or cable coach and a control coach. According to the direction of travel, either the motor coach or the control coach is at the head of the train. If necessary, several such units can be joined up and driven under multiple-unit control. In the control coaches, there is only one driver's cab at one end, further, as in the case of the interconnecting coach, they are provided with through control conductors and control-current couplings. The control and interconnecting coaches are transformed passenger coaches. The work was carried out by the NSR while the electric equipment was delivered by the A/S Norsk Elektrisk & Brown Boveri, Oslo.

(MS 564) *A. Brodbeck. (Mo.)*

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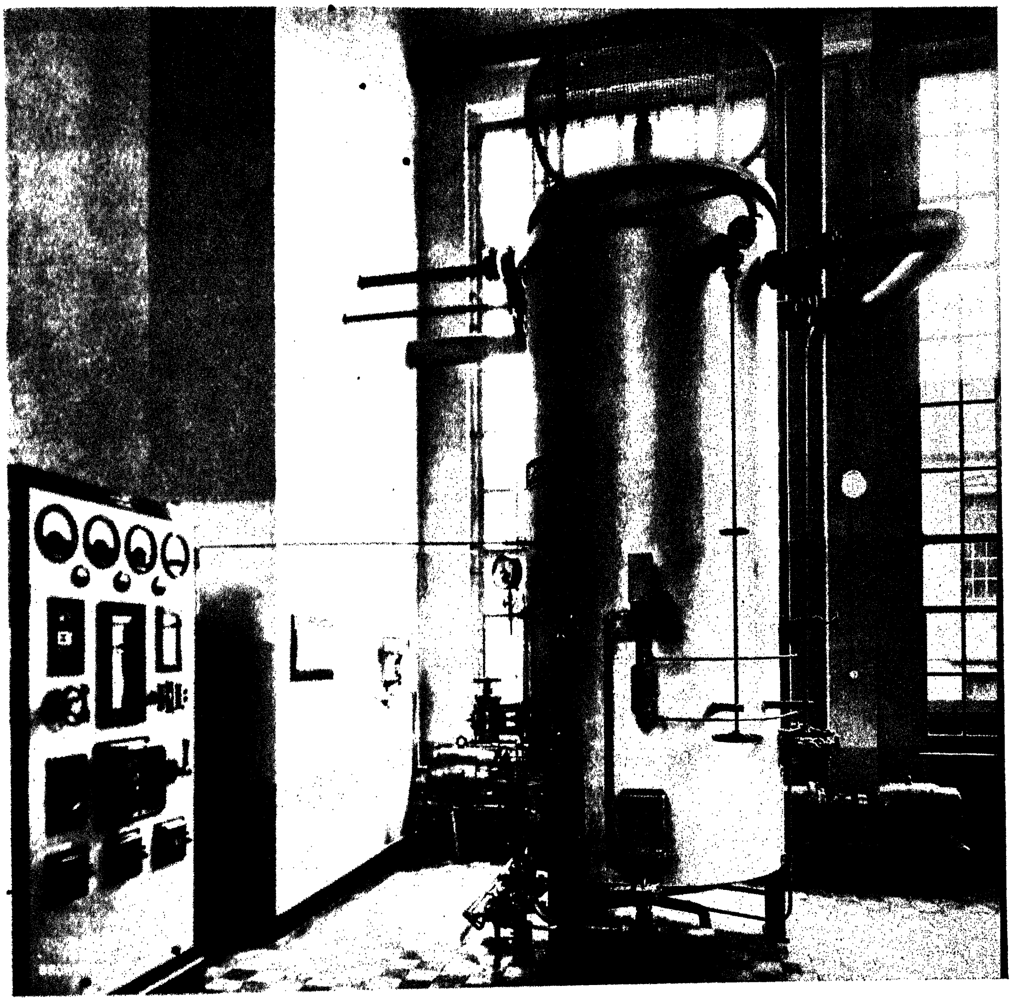

PAPIERFABRIK BALSTHAL (SWITZERLAND).
High voltage electric boiler for generating steam. Input 2000 kW, 10,000 V, 50 Hz, 17 kg/cm² abs.

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Printed in Switzerland.

BROWN BOVERI
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Single arc-welding machines

for direct-current and alternating-current welding

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THE BROWN BOVERI REVIEW
THE HOUSE JOURNAL OF BROWN, BOVERI & COMPANY, LIMITED, BADEN (SWITZERLAND)
VOL. XXIV DECEMBER, 1937 No. 12

THE TECHNOLOGY OF WELDING AND THE EXAMINATION OF WELDING WORK.

A SURVEY OF SOME TEST RESULTS.

Decimal index 621.791.7.

THERE can, hardly, be any other constructional process which has provided so many new angles of vision and opened up new practical possibilities as the technology of welding.

At first, the constructional possibilities inherent to welding were underestimated and it was with a certain amount of hesitation that the process was resorted to in order to join together parts which were of secondary importance and were only subjected to slight stressing. After a few years had elapsed, however, it came to be acknowledged that in many cases the welded structure was superior to a cast-iron, forged or rivetted one, in many respects. It is understandable that welding did not come into its own at an earlier date, because, at the beginning, the welded pieces were, simply, substitutes for cast or forged pieces, the form of the said piece remaining what it had been, that is to say a form conforming to the known principles of casting, forging or machining. The recognition that there was a design of pieces which was, itself, proper to the welding process and which opened up new constructional views and often differed from accepted conceptions, was a gradial one. To-day, however, there are many cases in which the conception and execution of a metallic construction can only be carried out with the help of welding.

There is no space here to go, further, into the interesting field of the influence of the technology of welding on the development of modern metallic structures and vice versa of the development of the welding process to meet the requirements of structural engineering. Brown Boveri has played an active part in this latter development and made use of welding, at a relatively early date, in the development of their own manufacturing programme. The firm was all the better placed to do so, as they build converter sets for D.C. welding and welding transformers for A.C. welding. This allowed of combining a thorough study of welding from the point of view of welding materials and welding technology with the careful investigation of the electric processes involved and the characteristics of the different types of welding machines. This allowed of developing high-grade welding able to meet all requirements. After a relatively short time, the superiority of arc welding by D.C. was demonstrated in a general way, as compared to A.C. welding, this as regards the technic proper of the process and the quality of the work produced. Autogenous welding is only used exceptionally and has a restricted field of application limited to that special welding work for which it has proved most suitable. In the following paragraphs, the references to welding and to welds as well as to results attained always concern arc welding carried out by D.C. unless otherwise stated specifically.

The following data shows the great importance attained by welding, to-day, in Brown Boveri constructional work.

The Grünewald pots used in the Grünewald bright annealing furnaces, which often work at temperatures up to 950 °C, are made of highly-alloyed chromium-nickel steel and are utilized under very trying conditions, on account of the high temperatures and frequent changes in temperature encountered. When cooling takes place, there is a vacuum created in the said pots and when this occurs, the pots must remain absolutely tight. Since the year 1928, a total of about 2500 of these pots, in completely welded construction, has been manufactured and put to work. The tanks of mutators having diameters up to about 3 m are entirely welded together electrically. These, also, must be absolutely tight because they work under the high vacuum of 1 1000 mm of mercury column absolute pressure. Since the year 1925, about 2000 of these mutator tanks have been manufactured. To these can be added the tanks of the transformers, in a variety of sizes, which are oil-filled and all four walls of which carry welded cooling ribs. Since 1922 these have been entirely of electrically-welded construction. Corrugated sheet-iron transformer tanks made of sheet-iron of 1—1·5 mm thickness have also been welded electrically since 1934/35. Some thousands of each type have been made and delivered. A step forward in steam-turbine design was accomplished when the welded turbine rotors were introduced. The replacement of a heavy and complicated forging by simple parts which could be joined together allowed of bringing out a lighter design which was a technical and economical improvement on the former one. Of these, new, turbine rotors, of which more will be said, 70 pieces

have been built up by the welding process since the year 1931 and they have given excellent results in service. Welding plays an important, indeed a decisive part in the construction of Velox steam generators, in which not only the pressure tanks of the water and steam separator and of the economiser are welded but all the evaporation elements, the superheater tubes and economiser tubes, as well. Since 1933, 38 Velox steam generators have been built, a big portion of which have been made under the strict supervision of the officials of the Swiss Steam Boiler Supervisory Association, which paid special attention to the welding work incorporated in the Velox. This enumeration of welding applications is, obviously, far from complete and only a few of the most striking applications are given. The utilization of welding processes in the whole manufacturing field is so varied and frequent that present-day manufacture and design cannot be imagined without its help. Mention should, also, be made, here, of the welding of the stators of electric machinery (Fig. 1), of that of the rotors of slow-running generators, of the welding of the gear wheels of traction motors, and of compressed-air tanks used in air-blast circuit breakers (Fig. 2), of frameworks and devices of all kinds.

The introduction of a new technical process on such a broad basis cannot be successfully carried out without extensive preliminary investigations made in material-testing plants. A description of all the tests carried out in conjunction with welding would fill a thick volume. The carrying out of welding tests has become so much a matter of everyday custom, that every time a new question arises, either from phenomenon observed during welding, or a defect occur-

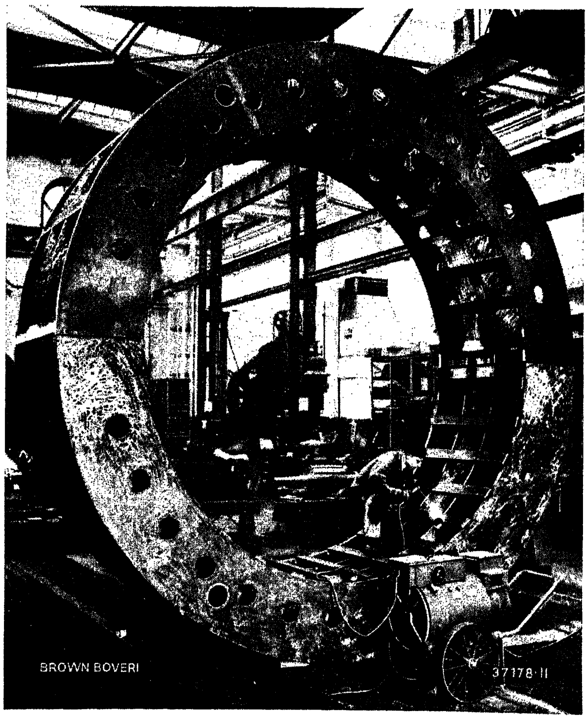


Fig. 1. — Welding a generator housing.

Fig. 2. — Compressed-air tank of an air-blast, high-speed circuit breaker after an internal-pressure test at 104 kg/cm² gauge, with considerable deformation but without cracks.

ring, or else a new material being used or some new electrode utilized, samples of the said welding are immediately made and sent in to the material-testing laboratory to be investigated, this quite apart from the multitude of simple technical welding experimental examples and tests carried out by the shop personel, themselves. Therefore, the following paragraphs will only be devoted to some of the interesting and important tests carried out on welded joints.

The quality of a welded joint does not depend, solely, on the electrodes, the material welded, the welding machine, etc., but also, and chiefly, on the welder himself. In plants in which it is not a question of automatic welding, primarily used to produce standard parts in mass production, that is to say always of the same or of similar design — which, unfortunately, is not the case in the Brown Boveri works — the greatest attention should be given to the reliability and skill of the welder. For this reason, Brown Boveri founded a welding-school where picked men of aptitude are trained theoretically and practically. Apart from a sure hand, reliability and honourability are demanded of these men because here, as in no other process, it is important that faults committed should not simply be covered up and passed over in silence, because, often, these faults cannot be detected on the finished piece afterwards, unless X-rays are used for the purpose, which is not practical in all cases. It should be said here, however, that the introduction of a subsequent examination of welding work by X-rays has gone far to raise what may be termed the standard of welding (supervision number). The work of welders, whose training is over, is observed and controlled at regular intervals after the said training is finished, this by *welding examinations*. This is done by examining certain test pieces with butt welds, fillet welds, shear fillet welds, without the welder who has carried out the work being aware that this will be done. In this case, the seams are such as are encountered in ordinary structural work carried out with iron sheeting and unalloyed electrodes. The following tensile strengths were attained, in recent times, by different workmen:—

Date	Fillet weld kg/mm²	Shear fillet weld kg/mm²	Butt weld kg/mm²	Impact value of the welded material mkg/cm²
III. 1935	34·1	31·2	34·0	
	31·1	31·2	33·4	
	34·6	34·0		
	33·5	33·4		
	32·2			
	33·7			
X. 1935	35·0	37·8	32·5	8·7
	36·0	35·4	32·5	8·4
	35·3			8·9
	36·4			10·0
VII. 1936	39·0	39·2	52·7	7·9
	36·5	38·6	52·5	7·6
IX. 1936	38·8		48·1	6·7
	37·6			

For the purpose of comparison, it may be added that the German standard rules for elevated steel structures (DIN 4100) calls for the following minimum values for the specified welder examinations and for the same tests:— for fillet welds min. 26 kg/mm², for shear fillet welds min. 24 kg/mm², for butt welds, since 1936, at least 37 kg/mm² while the impact value of the weld is not tested at all.

Comparative tests with different welding machines are of importance, the said machines having different current-voltage characteristics. In this field, mention should be made of a work the object of which was to determine the difference between welds made with different welding machines having different characteristics. With each machine, ten tests were carried out with electrodes without and also with coatings. Further, welding beads were produced in each case with two electrodes to investigate penetration conditions. As the machines differ chiefly by the magnitude of the short-circuit current, it was specially interesting to determine the effect on the structure of the weld of a short circuit of several seconds duration (electrode burning on the work). The results showed that the average value of the ultimate tensile strength only varied slightly between the four machines but that the irregularity of the different values was greatest on a machine built by a competing firm. Further, coated electrodes proved much superior to bare ones as regards constancy of quality. The penetration measurements of the different beads showed no considerable disparity between the machines. Metallographical investigation of the structure at the points where short circuits were intentionally produced, showed that the influence of short circuits is generally overvalued. In many cases, there is no difference to be detected at all as compared to the other welds, in other cases there was a deepening of the penetration, in which there were sometimes bigger slag contents. With coated electrodes, the penetration was somewhat greater than with bare electrodes, on account of the greater concentration of heat. Speaking generally, it was also shown here that the differences due to the different machine ratings and current conditions only showed up under very careful welding work and with very high-grade electrodes, but that, generally, differences are greatly outweighed by the factor of the different kind of electrodes used and by that of the skill of the welder himself. Similar tests were made with A. C. welding, in order to determine differences between single- and three-phase current. These tests were carried out by three welders working on three different thicknesses of sheet metal and with two different kinds of electrode. In this case, as well, of the different influences making themselves apparent, those depending on the kind of electrode used and on the different workmen were much greater than those due to the kind of welding current used or the thickness of the metal worked on. A comparison of different types of welding-current regulator, in another series of tests, shows that these regulators either facilitate or render more difficult the work of the welder, as the arc is either made to burn more steadily by the regulator or rendered unsteadier, thereby, and, thus, influences the guidance of the electrode. Thus, the results attained are somewhat at variance due to this indirect cause and only some special regulating apparatus can be said to give undoubted and considerable improvement. These tests were carried out horizontally, vertically and as overhead work just as in ordinary structural welding (iron sheeting, bare electrodes, unannealed), the following welding strengths which are an average from 30 different tests, were obtained:—

	horizontal	vertical	overhead
Ultimate tensile strength kg/mm²	33·8	34·2	38·8
Bending angle of bending test in degrees (R=s/2)	56·3	41·2	35·7

The *investigations into new kinds of electrodes* is a considerable chapter to itself. The development in this field has made such rapid progress that, every year, new investigations are necessary. In the course of last year, a total of about 20—30 kinds of electrode were tested. While, in earlier days and for ordinary welding work, as pure a non-alloyed iron as possible was used having a low carbon content, such as is still employed, as a matter of fact, in many cases, there is a tendency, to-day, to use a slight alloy for the electrode rods used on ordinary structural welding work, that is about 0·5 % Si and up to 1 % Mn or with 2 % Ni when severer conditions are imposed. Sometimes, the alloy element is contained in the rod itself and, sometimes, it is located in the coating and is only introduced to the welding when the metal fuses. In the case of alloyed rods, the fundamental rule of always using the same alloy as that of which the material worked on is made is being more and more discredited, because the use of another composition of alloy has often advantages, as, for example, in the case of

austenitic welds for non-alloyed or weakly-alloyed structural steel.

The coating of the electrodes is mostly composed of slag-producing material such as asbestos, chalk, plaster, clay also of carbonates, silicates and metallic oxydes, while alloy elements in the form of powder of corresponding ferro alloys are added such as ferro manganese, ferro-chromium, ferro aluminium, etc. As a binder, for the whole, water glass is, usually, used. A very valuable quality of the modern electrode sheath is that the layer of slag it forms comes away very easily once the iron solidifies, a slight blow with a hammer suffices to detach the whole layer of slag which comes away in big flakes, which facilitates cleaning the welded regions. A comparative investigation on three electrodes for welding boiler plating, carried out according to the specification of an important customer, gave the following results.

Kind of electrode	Not annealed: Ultimate tensile strength in kg/mm²	Elongation in %	Bending angle R=s	Bending angle R=s/2	Annealed up to 880° C: Ultimate tensile strength in kg/mm²	Elongation in %	Bending angle R=s	Bending angle R=s/2
St.	45·3	9·4	159	160	40·7	36·6	180	180
Pr.	44·4	7·0	180	128	40·3	13·5	180	180
Ex.	44·1	9·7	180	180	40·1	14·4	180	180
					Annealed up to 650° C			
St.					42·8	50·2	180	180
	Boiler plating not welded:—				41·0	26·0	180	180

These are average figures taken from a big number of separate tests. The three electrodes all gave about the desired and specified strength of the boiler plating, they differ, however, in elongation which was measured over the weld. It is, also, important to note that the annealing of the weld at temperatures above the transition point given above does not produce better results than a stress relieving treatment at 650° C. High annealing is, even, often very risky owing to the deformation of the work which it may cause. As an example of a so-termed complete electrode investigation the following may be of interest:—

1. *Electrode rods.*

Analysis:

C %	Si %	Mn %	P %	S %
0·04	0·01	0·43	0	0·02

Tensile strength = 55·8 kg/mm².

2. *Coating.*

Analysis:

SiO_2 %	Na_2SiO_3	CaO	Fe	Mn	Al	CO_2	Humidity
12·43	30·7	5·6	23·6	17·9	2·54	4·9	2·22

Thus, the sheath is composed of slag-forming materials (silicates and chalk), alloy element (manganese) and desoxydizers (aluminium).

3. *Results of tests of the welded material.*

Tensile tests:—

	Elastic limit (0·02 %) kg/mm²	Young's modulus kg/mm²	Yield point kg/mm²	Ultimate tensile strength kg/mm²	Elongation %	Contraction %
D. C.	—	—	51·6	61·8	16·0	26
	50·0	20,400	50·0	61·0	20·5	49
	51·0	20,500	51·0	60·8	17·0	27
A. C.	49·0	20,200	49·0	60·6	16·7	23
	47·0	20,200	47·0	59·8	22·5	54
	46·0	20,200	46·0	59·2	26·2	54

Impact and bending tests:—

	Impact value mkg/cm²	Yield point of bending kg/mm²	Brinell hardness: Plating	Fusion zone	Welded metal
D. C.	6·8	80·0	120	142	170
	7·1	79·2			
A. C.	7·2	75·5			
	8·1	73·8			

4. *Results of tests on the welded joint:—*

	Ultimate tensile strength in kg/mm²: Rough welding	Machined welding	Bending test: Bending angle in degrees
D. C.	46·0	54·5	180
	42·8	54·8	180
	41·4		
A. C.	37·4	49·5	180
	38·0	53·6	180
	38·0		

5. *Macro-etching.*

Etching tests through the welded metal and through the welded point show a very homogeneous material quite free of pores. The rods taken from the welded work cannot be distinguished in the unetched condition from those taken from rolled steel.

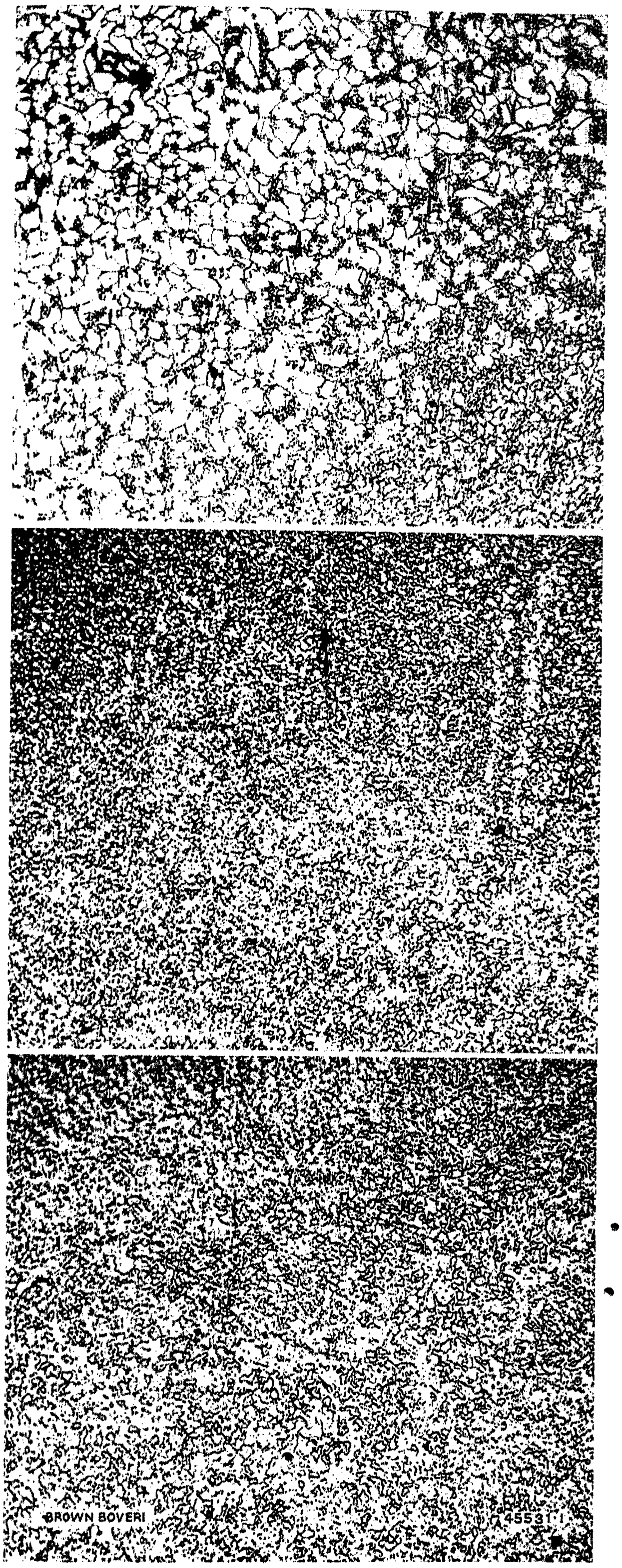
6. *Micro-investigation.*

The structure of the welded work is very finely grained and strikingly uniform. It is composed of ferrite with a little pearlite (Figs. 3, 4 and 5). The transition from plating to weld is quite gradual. There are very few slag inclusions to be detected.

7. *Investigation of penetration.*

Average breadth of bead	Height	Depth of penetration	Thermal zone of influence
15·36 mm	2·4 mm	2·3 mm	2·8 mm

Special structural problems also call for special welding investigations. Thus, in the design of steam generators and of steam turbines, the problem often arises of *welding together cast steel and boiler plate*, or other pieces. For this reason, a series of tests were carried out in this field of which the following are reproduced, herewith; these are specially



Figs. 3, 4 and 5. — Structure of a weld (enlarged 100 times).

(Above): Zone of plate influenced thermally.

(Centre): Transition from weld to plate; the limit can only be discerned by the shape of the slight slag content; longitudinal in the plate and round in the weld.

(Below): Structure of welding material.

interesting because of the comparison of electric and autogenous welding. The average results of all the separate tests, a detailed description of which would lead too far, can be approximately summarized as follows:—

	Yield point in kg/mm²	Ultimate tensile strength in kg/mm²	Bending angle in degrees
Boiler plating	25	40—41	180
Cast steel	27—30	44—47	abt. 90
Weld:—			
Autogenous welding .	—	30—37	76—132
Electric welding with:–			
V electrode . . .		39—52	26—47
St electrode . . .		41—52	45—87

Cast steel and boiler plating, thus, present no difficulty to being welded together (Fig. 6). The autogenous welding work produces the lowest tensile strength but the best bending results, the two electric welding tests are of equal value, as regards tensile strength but St is better as regards the bending test. It should be added that these examples of welding work were, mostly, annealed, which caused the bending test results to attain higher figures here, as well.

The welding of sheet-metal structures composed of *thin alloyed sheeting of great tensile strength* calls for very great care and supervision. The introduction of these materials to structural work was, therefore, made the subject of a series of tests. The problem which arises, here, is the hardening of the sheeting which occurs in the neighbourhood of the weld and the resultant tendency to fissure. The tests, therefore, were made to cover, among other points, the thermal treatment of such welding seams. A series of tests gave the following average results:—

	Not annealed		Annealed at 650° C		Annealed at 580° C	
	Ultimate tensile strength in kg/mm²	Bending angle R=1·3 s	Ultimate tensile strength in kg/mm²	Bending angle R=1·3 s	Ultimate tensile strength in kg/mm²	Bending angle R=1·3 s
Sheeting:—						
Unwelded	102	180	71	180	75	180
Welded with:–						
Electrode BF	100	41	82	89	—	—
Electrode V	85	10	82	—	83	96
Electrode N	73	46	73	176	73	—

It was shown that an annealing treatment has a strong influence, not only on the weld but on the plate, itself, as regards its strength, but that, on the other hand, if this annealing is omitted the chromium-nickel steel in question gets brittle due to the tendency to harden. The solution of these difficulties lies in taking suitable thermal and mechanical mea-

sures during and after the welding process. Other tests were carried out to examine the possibilities offered by normalizing at 850° C or also by a heat treatment which would also impart to sheeting of 3 to 4 mm thickness an ultimate tensile strength of over 70 kg/mm².

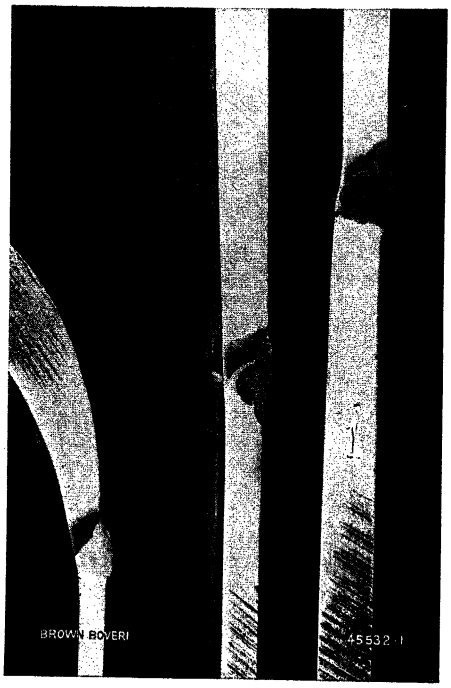


Fig. 6. — Section of a welded evaporator element. Three concentrical steel pipes are welded at one end to a cast steel head (natural size).

The welding of *high-alloyed austenite structural material* is especially advantageous and easy. This material is used, partly, in making electric furnaces and, partly, in building machines for chemical purposes where they are frequently employed, owing to their resistance to scaling and corrosion. These austenitic steels with 20% nickel and 16 to 20% chromium cannot harden, owing to their structure so that all difficulties on these grounds are eliminated. Further, on account of their high resistance to corrosion, they have little tendency to oxidization during welding and, thus, show little slag inclusions and binding faults. The main advantage of these steels is, however, their great toughness. The results of such weldings are, therefore, good, in all respects.

Steel	Not welded		Welded			
			Specimen rod with welding bead		Specimen rod without welding bead	
	Ultimate tensile strength in kg/mm²	Bending angle R = s	Ultimate tensile strength in kg/mm²	Bending angle R = s	Ultimate tensile strength in kg/mm²	Bending angle R = s
07 Cr 17 Ni 21	56	180	64	180	58	180
08 Cr 17 Ni 9	63	180	75	180	67	180
18 Cr 18 Ni 19	76	180	84	156	77	180

Further tests were for the purpose of comparing electric and autogenous welding carried out on similar steels:—

Steel	Unwelded	Welded electr.	Welded autog.
07 Cr 17 Ni 21	66·5	73·0	64·3

Electric welding should be given preference, here, not only on account of the great tensile strength but also because of the danger of carbonization of the fluid metal when the welding flame of the burner is badly regulated. This is a very important point because such welds which are carbonized are subject to so-called weld decay an intercrystalline corrosion which can have very deleterious effects. It is of great importance that all austenitic materials should be tested as to whether they are subject to this welding decomposition. There are two measures to take to guard against this weld decay.

1. The C content must not exceed 0·05 0·07 %.

2. About 0·5 % of Titanium or Colombium must be added to the alloy.

Thus, for example, the intergranular corrosion test of the welding specimens of the previous investigation showed that the specimens of 18 Cr 18 Ni 19 were entirely destroyed, while the two other steels 07 Cr 17 Ni 21 were unaffected, to a great extent. The only reason for this is that the C content is 0·18 % in the first case and 0·07 0·08 % in the second case. It is interesting to make a comparison of the weldings of such steels carried out, partly, in Brown Boveri's Baden shops and, partly, in the works of their foreign concessionaries.

	Average ultimate tensile strength in kg/mm² With welding bead	Average ultimate tensile strength in kg/mm² Without welding bead
Welded in Baden	82·8	69·7
Welded in works of licencees	83·8	69·8

Austenitic electrodes were, naturally, also used for the welding of high-class alloy blades such as are used in gas turbines. The tests on blade weldings of this type give the following results:—

Yield point	Ultimate tensile strength	Elongation	Contraction
kg/mm²	kg/mm²	%	%
54·2	68·1	21·3	31·0

The micro-examination showed that the weld was quite tight and was exempt of foreign components or pores. Further, these specimens were tested for weld decay immediately after the welding as well as after a heating-up treatment lasting 15 hours, at 650° C and it was shown that, in both cases, after more than 100 hours of attack by the test solution, the steel and the welding material were entirely untouched and remained tough.

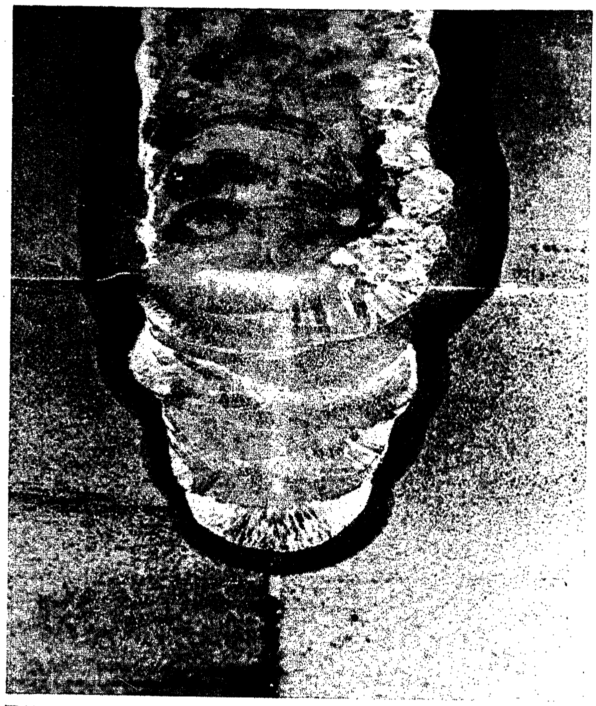
Considerable inner tensions are set up in the weld whenever a welding operation is carried out. The magnitude and distribution of the said tensions are difficult to determine. It is, therefore, interesting to

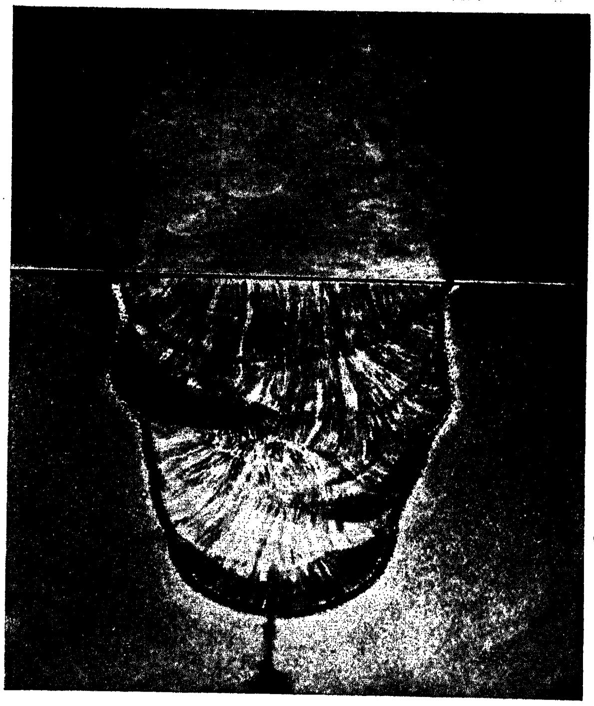
investigate what the conditions are under which these tensions arise. This was carried out in collaboration with the Swiss Steam Boiler Association and took the form of a series of tests during which the contraction and deformation of welded joints which were made under different conditions were observed. In the case of pieces which were not held rigidly in position, a contraction of the weld took place perpendicularly to the weld and amounting to about 1 mm, to this must be added a deformation of the plate after the first weld layer was put on, which went on increasing as the subsequent layers were added. If, however, subsequent welding is carried out on the other side of the plate, a remarkable reverse deformation takes place. The deformation is considerably reduced if the piece being welded is rigidly secured. The type of weld carried out exercised a very distinct influence on the deformation of the piece, thus the V weld produced the greatest deformation, the double V weld the slightest deformation, while the effect of the U weld is between the two others. If when a double V weld is being made, care is taken to carry out alternatively a layer above and a layer below, the deformations to which the welded piece is subjected are, practically, eliminated, even though the said piece is not constrained at all. The thickness of the electrode plays a part, here, in so far as thick electrodes deform the piece less than thin electrodes. Further investigations were devoted to reducing the inner tensions due to welding. Annealing is the best way of eliminating them. Our investigations which are not concluded yet, show that after annealing at 650° C, a welded structure, is, really, entirely freed of internal tensions. The remaining tension is measured by the change of form which occurs when two U-shaped specimen rods, which are welded end to end, are cut. This change in form is about 40 times smaller after the heat treatment than in specimens which are not annealed. Another way of reducing the inner tensions is to superimpose on them external forces and, thus, to attain the yield point locally at the tension peaks, which causes a plastic expansion at the spot in question and a reduction of the tension peaks. It is possible, in this way, to reduce the original tension considerably by a load which does not attain the yield point of the piece, so that when this pre-loaded specimen is cut, much less change in form is observed. If the preliminary load attains or exceeds the yield point the inherent tensions of the piece, also, practically vanished.

In the introduction of the welding method to the *manufacture of hollow turbine rotors built up of several parts*, a number of problems were, obviously, encountered which called for corresponding investigations. The first attempts to weld alloyed structural steels of big wall thickness first produced considerable hardening of the steel in the neighbourhood of the weld. This was due to the critical rapidity of cooling, required for the hardening of steel sensitive to being hardened, being exceeded when the heat from the fused metal and its surroundings is carried off too rapidly. This is due, practically entirely, to radiation and conductivity. The result is that big surfaces and thin walls, i. e. sheet-metal structures are subject to the danger of hardening as a result of intensive radiation while big sections and masses are subject to the same danger on account of high heat conductivity, because, in both cases, the rapidity of cooling is too great. This is made clear when it is noticed that the welding bead laid down on a massive piece cools down to a temperature which can be born by the hand, in almost less than one minute; the temperature drop accomplished in this short period being from 1500° C to about 70° C. This is a quenching process which is considerably faster than, for example, the quenching of the same piece in oil during annealing. It is obvious that this hardening is a big danger and, for this reason, all welded turbine rotors are subjected to a careful and prolonged annealing process at 600—650° C. Tests by Brown Boveri showed that, after this, the hardness near the weld is reduced to about 5 % that is to say has been, practically, eliminated.

To this end Brown Boveri carried out welds on special specimen parts of great thickness, with different kinds of electrode and then examined these pieces, minutely, both metallographically and with the Brinell test (Figs. 7 and 8). It is advantageous to carry out welding of this kind with austenitic electrodes because, with these, the welding material itself is sure not to get hard and, also, it will possess excellent elongation and deformation qualities. This last point is of importance in order to avoid the formation of cracks which may also be prevented by suitable design of the parts and arrangement of the weld itself so that the contractions occurring are taken up both by the flexible structure and by the tough weld. The danger of a fissure is maximum during the welding process and, therefore, great supervision must be exercised during the said work. After every welding layer, the weld has to be conscientiously cleaned and, even, machined and then investigated under a magnifying glass for cracks. After annealing, of course, the tensions and the danger of fissures are completely eliminated, as said before. In so far as hardening and inner tensions are concerned, these built-up rotors are, thus, quite faultless (Figs. 9 and 10). Numerous and thorough examinations of material and analysis carried out gave Brown Boveri the desired information on which were the right and the wrong alloys to be used in built-up welded designs. It was found necessary to specify to the steel works exactly the composition of the various alloys, which is checked up by analysis when the material is delivered from the steel mills.

Practical welding tests on the best shape to give to the weld and its surrounding area were completed by making cross sections of the weld and etching tests and these showed that an intermediate shape between a U and a V seam was





Figs. 7 and 8. — **Weld in high-grade structural steel of a turbine rotor (enlarged 1·5 times).**

(Above): Before annealing, a clearly-discerned zone of hardening is seen on the work near the seam.

(Below): After annealing at 620° C, the zone of hardening has completely disappeared.

Fig. 9. — **Discs and shaft ends of a welded turbine rotor, before welding.**

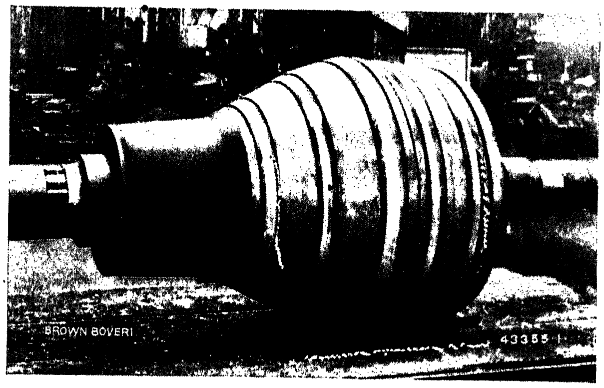


Fig. 10. — **The welded rotor being turned up.**
The long and unbroken turning from the weld will be noticed.

the most advantageous, here. Although, really, the stressing of the weld in the turbine rotor is very low, the importance of the organ welded made it seem advisable to carry out a series of load tests with welded rotors. To begin with, big plates with circular weld were welded together; these were made of alloy steel with an ultimate tensile strength of 70—80 kg/mm². These were tested under internal pressure up to a stressing of the weld of 32 kg/mm². Simultaneously, one side of the container thus formed was heated up to 230° C in order to reproduce, here, the tensions set up by unequal temperature distribution in the rotor. The weld stood up to these stresses (without counting the additional bending effect) without revealing any defect, this although the plates, which were 50 mm thick, were considerably distended outwards by the inner pressure. Apart from these tests, a completely-welded rotor of 500 mm diameter was also subjected to an impact test, it being supported free at the two shaft ends and bent by the sudden impact of a 3·2 ton weight falling on its centre. Up to an impulse energy of 3220 mkg no deformation big enough to be measured was detected. Increasing the drop of the weight caused deformations but rupture only ensued at 4740 mkg. The speed of the impact was about 5 m/s. The rupture in its whole length did not follow the weld at any part or the zone thermally influenced by the weld; the crack was 7—10 mm away and was in the steel of the rotor body. This shows clearly that a hollow rotor welded together like this can stand up to heavy impact shocks, just as well as one built of one piece. After the resistance of the rotor to static and impulse stress-

ing had been determined, there only remained the resistance to vibrations to be proved. To this end, a welded model, somewhat smaller than the standard rotor but otherwise welded according to standard methods, was rigidly secured at one end while the other prolonged shaft end was mechanically caused to vibrate. Further, with some rotors, the bending stress thus brought about was increased by a tensile stress produced by inner water pressure. Here, as well, the results were excellent. Quite considerable stressing applied in progressive severity was stood up to nearly 40 million times before rupture took place. Very valuable data was collected from the different shapes of the welds, this as regards the layout of the weld in relation to the slots machined in the rotor to take the blades. Thus, this rotor design stood up to the most dangerous oscillations and also to the impact and to static stressing such as can never occur in a turbine.

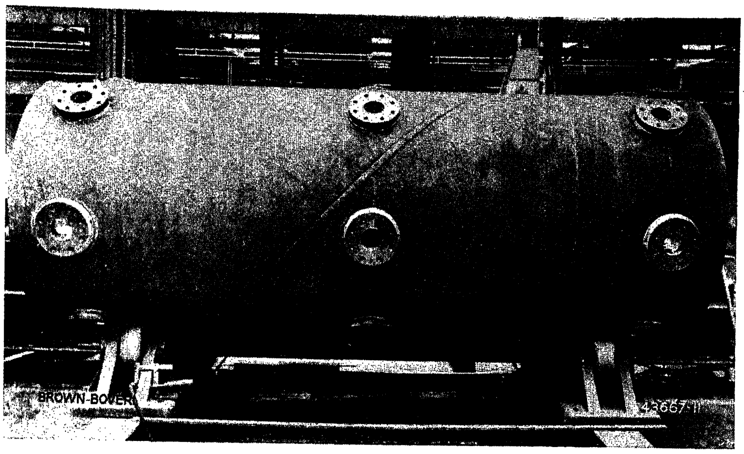


Fig. 11. — Welded mantle of a preheater, wall thickness 42 mm.

The welding of the pressure chambers forming parts of *Velox steam generators* is work of equal importance to that of turbine rotor welding. These chambers have to stand up to 50 kg/cm² gauge and more at temperatures up to 260° (Fig. 11). Of course, these parts are mostly subjected to the official regulations for steam boilers and, being new designs, are tested with the greatest thoroughness before being passed. Therefore, the material used and, especially the welds are subjected to rigourous investigations (Fig. 12). If, now, a whole series of boiler weldings are tested and passed by a variety of State officials and those of private organisations, this is the best proof that the design in question will meet severe requirements. It should be mentioned here that the Lloyds' Register of Shipping has given Brown Boveri their consent to the building of boilers in this design, after through and exhaustive investigations as to reliability and has placed Brown Boveri on the list of admitted manufacturers of fusion-welded pressure vessels. These preliminary tests were not limited to exact supervision of the welding work in the shops by a welding surveyor, but the training of the welders and regular control of the said training was also investigated and made an absolute condition of acceptance. The quality of the work had to be proved by extensive welding tests carried out with different electrodes. The following average values were attained:—

	Yield point in kg/mm²	Ultimate tensile strength kg/mm²	Elongation %	Bending angle R = s/2
Electrode E annealed	27·8	44·4	44·0	180
not annealed	31·1	47·4	34·0	146
Electrode S annealed	27·7	43·4	47·2	180
not annealed	31·1	44·2	26·3	180

These tests were completed by hardness tests on and near the welding seam, by micro and macro examinations as well as by alternating fatigue tests which will be mentioned further on. The Routine tests of Lloyds' Register of Shipping on two Velox steam generators were even more exhaustive than these preliminary tests. The following were called for:— tensile tests on the weld material proper, impact tests on the fusion zone from weld to plate and in the weld itself, tensile tests of the welded joint, bending tests, determination of the specific weight of the pure weld for controlling the porosity, macro-etching tests and micrographs of plating, transition point and weld. Further the entire length of the weld was X-rayed and photographed (Fig. 13) and this showed not one fault anywhere which made repair work necessary. It would be beyond the scope of this article to tabulate all the test figures; all the tests were entirely satisfactory. Another steam generator was built to the well-known American ASME Boiler Code, and here the testing of the welds was carried out in similar manner to the British Lloyd ones and successfully. A further very exhaustive testing of our welding work was carried out by the organs of the Italian State Boiler Supervisory Association, the

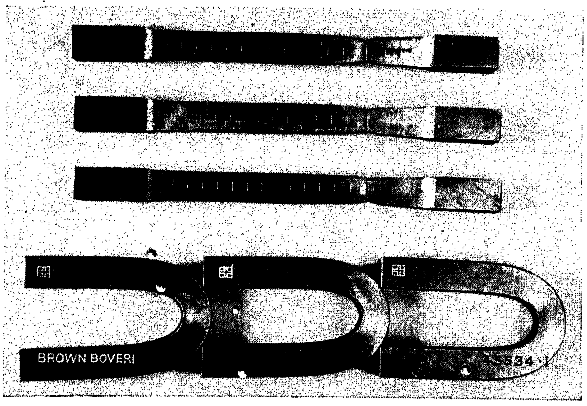


Fig. 12. — Tensile and bending tests on a welding of boiler plating 42 mm thickness.
The rupture occurs beyond the weld.

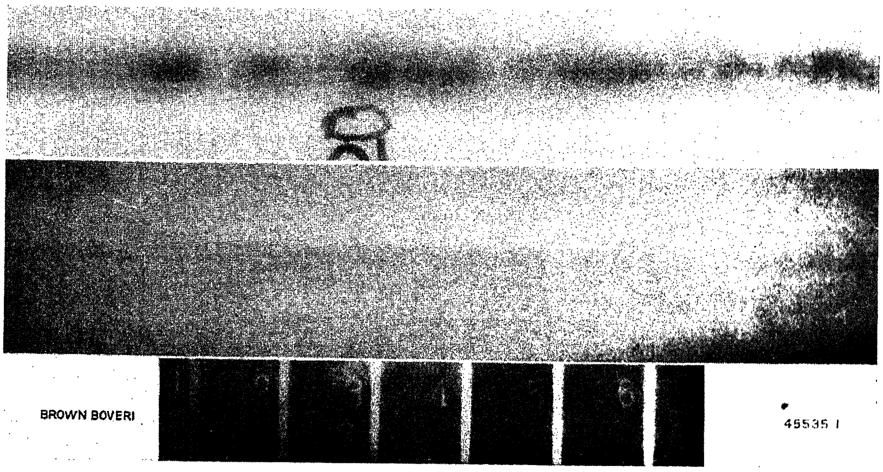


Fig. 13. — X-ray photographs of welds (reduced 0·45 times).
(Above): Weld not turned up.
(Center): Weld turned up.
(Below): Test plate with milled slots to judge of the reliability of fault investigations. The numbers stamped in give the depth of the slots in percentage of the thickness of the plate (27 mm).

ANCC, for a boiler to be delivered to Italy (Fig. 14). Other steam generators were built to meet Norwegian and Indian requirements etc. Each acceptance test fills a considerable testing report. Brown Boveri carried on supervision of the quality of their welding work in parallel with these very severe official tests, just described.

To conclude, something must be said on certain individual investigations to *determine special qualities.* In a great many cases, welding is used for parts which are subjected simultaneously to severe stressing and to high temperatures and the question arose of whether a weld behaved differently from steels of the same nature under high temperatures. In connection with the welded-in blades of turbine wheels, tensile tests were carried out under high temperatures on joints of this nature made with different kinds of steels and these led to the following results:—

	Ultimate tensile strength in kg/mm²	
	at 20° C	at 450° C
Ni steel 3 Ni 2 welded with non-alloyed electrodes	55·7	50·2
Ni steel 3 Ni 2 welded with high-class alloy electrodes . . .	72·1	54·9
Cr steel 2 Cr 13 welded with high-class alloy electrodes. . . .	63·5	52·9
CrNi steel 3 Ni 2 Cr 1 welded with high-class alloy electrodes . .	67·1	52·7

For continuous stressing at high temperatures, however, as is well known, the creep limit and not the ultimate tensile strength is the deciding factor, which takes the creep behaviour of the steel into account. Creep tests on welds like this carried out with alloyed electrodes are difficult to make and to estimate satisfactorily because, apart from the weld itself, the material of the part welded takes part in the elongation measured and this in a proportion which cannot be estimated with precision. This is very much the case when the welded seam has not been machined flush, as happens in most steam pipe and boiler constructions. Now, instead of this, it is possible to make the tests on specimen rods taken from pure welding material although the characteristics thus revealed can never give their full effect in the weld itself on account of the inner tensions exercised in many axis. The following are the results of tests of this kind carried out on soft boiler plating and corresponding unalloyed soft electrodes.

	Yield point	Creep limit		
	at 20° C	at 300° C	at 400° C	at 500° C
Tests on welded joints:				
Boiler plating				
not annealed . . .	31·0	22	11	4
Autogenous welding	24·6	18	8·5	4
Electric welding . .	25·1	18	11	4
Tests on pure welding material:				
Autogenous welding	22·9	13	6	<1
Electric welding . .	28·0	14	7	2

We have indicated the yield point, here, at 20° C and not the ultimate tensile strength (which

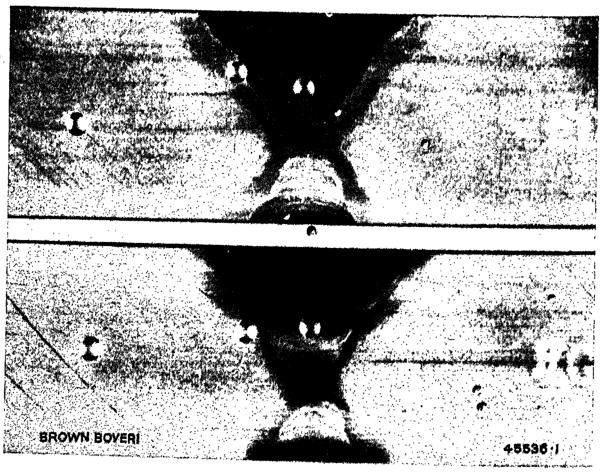


Fig. 14. — Macro-etching tests of a boiler welding (with Brinell hardness test). Full size.

is about 38 kg/mm²) because the yield point at low temperatures gives a value analogous to the creep limit at high temperatures, which interests the constructor. Other tests cover the determination of the resistance to alternating stresses of welded joints. It is very important to take into account the behaviour of welded structures under alternative stressing, because a weld, like any other structural geometrical or mechanical unhomogeneity in the material, may be the cause of tension increase by notch effect which may produce the dreaded fatigue rupture.

In this respect, the height and shape of the welding bead plays an important part as well as the penetration notch beside the bead. Further, the amount of pores, gas pockets or slags contained in the weld is of great importance because these factors may reduce the resistance to alternative stresses considerably. This has been demonstrated by tests with sound welds free of pores and with others chosen specially on account of their porosity. All the specimen rods were tested on a vibration-testing machine built to the Wöhler principle, the test being on rotating bending stress at 15 kg/mm². The specimens stood up to the following number of alternative loadings:—

	Number of alternative loadings at 15 kg/mm²	
Porous weldings	495,510	broken
	779,700	„
	483,760	„
	836,130	„
Weldings free of pores	15,651,610	did not break
	16,278,700	„ „ „
	16,697,910	„ „ „
	16,560,900	„ „ „

The influence exercised by an annealing process at 600 °C on the strength against vibrations was the subject of other tests. These were made on soft boiler-plate weldings and for Lloyds' Register of Shipping.

This shows that an annealing process of this nature does not influence the fatigue strength in any considerable and decisive way.

		Fatigue limit in kg/mm²
Electrode E	annealed	16·7
	not annealed	17·5
Electrode S	annealed	17·5
	not annealed	15·5

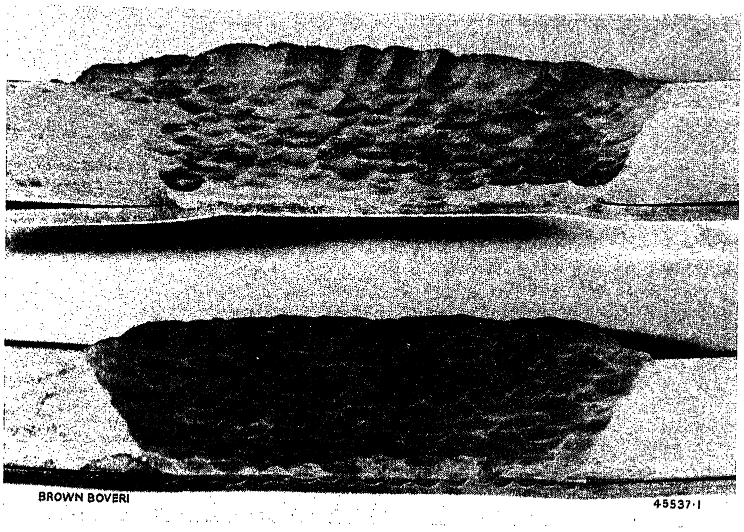


Fig. 15. — Macro-etching of a welding layer to take specimens from of pure welding material, across direction of the weld. Full size.

A certain interest is attached to tests on *specimen rods made of pure welding material.* As many welding layers were laid on as was necessary to allow of cutting out the requisite standard size specimens for tensile, impact and bending tests (Fig. 15). While, a few years ago, these specimen rods turned up and finished would have been characterized by more or less porosity and foreign matter, considered inevitable, at that time, it is possible to-day to get specimen rods absolutely clean which cannot be distinguished, even by an expert, from rods of unwelded rolled steel, this thanks to the progress made in electrode manufacture and in the technic of welding. Some of these

Electrode	Yield point kg/mm²	Ultimate tensile strength kg/mm²	Elongation %	Impact values mkg/cm²
Boiler weldings:				
St not annealed	34·7	45·6	33	
StE not annealed	35·0	45·0	40	
	Bending tests bent through 180° without cracks appearing			
As unannealed	33·8	46·1	21	
ST annealed	36·0	44·0	25·6	13·1/14·9
	35·6	43·6	25·0	13·4/13·1
	32·8	42·4	20·0	13·7/15·0
	33·0	43·4	24·7	12·0/11·5
	38·4	46·5	19·2	8·7/8·2
	32·7	43·6	18·8	10·6/10·2
	32·5	43·3	26·3	13·4/12·9
	31·2	43·1	23·0	13·3/12·0
	The specific weight of 8 specimens of welding material is between 7·82 and 7·88			
ST annealed	26·2	46·6	29·0	
	37·1	47·6	30·0	

Electrode	Yield point kg/mm²	Ultimate tensile strength kg/mm²	Elongation %	Modulus of elasticity kg/mm²	
Structural weldings:					
V not annealed					
with D. C. . .	35·7	43·4	18·8	20,400	
with A. C. . .	35·0	43·2	15·8	20,400	
With D.C. and A.C.	Yield point of bending test 60·0 kg/mm²				
S not annealed .	42·9	52·3	11·0	Impact value mkg/cm²	
Cr not annealed .	36·9	49·1	24·0	8·8	
	37·6	49·1	19·0	6·1	
	38·2	47·9	25·0	9·9	
	Yield point of bending test 63·0—63·3 kg/mm²				
S not annealed .	44·0	55·5	22·0	6·1	
	44·0	54·6	12·4	7·7	
	44·6	55·2	20·0		
	Modulus of elasticity 19,650 kg/mm²				
BF not annealed .	41·8	52·9	15·0	9·7	
	45·2	53·7	14·0	11·3	
	44·6	54·8	20·0		
	Modulus of elasticity 20,800 kg/mm²				
S not annealed . (determined by an official testing laboratory)	41·4	55·5	29·4	14·1	
	41·4	55·1	31·9	15·0	
	42·9	55·9	28·4		
				Yield point of bending test kg/mm²	Modulus of elasticity kg/mm²
S not annealed					
with D. C. . .	51·6	61·8	16·0	80·0	20,400
	50·0	61·0	20·5	79·2	20,500
	51·0	60·8	17·0		
with A. C. . .	49·0	60·6	16·7	75·5	20,200
	47·0	59·8	22·5	73·8	20,200
	46·0	59·2	26·2		

Figs. 16 and 17. — Formation of different iron nitrides in welding with bare electrodes (enlarged 1500 times).

tests are given here, all the values given being taken from specimens of pure welding material only.

As is seen, the welding material attains qualitative values which are in no way inferior to those of the steel, itself. Nevertheless, we would emphasize here that, in the case of a weld in a three-dimensional piece of work, the values given in the preceding table can only be applied as such conditionally because the tensions exercised along different axis cause various stresses in different senses which results in such points in the piece itself standing up to considerably higher stressing than would be expected from the results of the tests.

In this summarized report, we can only touch briefly on certain fields and cannot pretend to cover the multiple applications of welding. For example, no mention is made of the welding on of special machine-tool steels to a steel holder, the welding of aluminium and other non-ferreous metals, further, for example, of butt welding of copper conductors in the winding of electrical machinery, repair welding of cast iron and cast steel, the welding of layers of resistant material to stand up to wear, spot welding, pipe welding in ducts, preheaters and superheaters, etc. Further, only the mechanical field of testing has been touched on without going into details of micro-tests which give information on the diffusion phenomena during the welding of different alloyed steels, on the structure under different welding conditions and in the various zones and on the nitrogen absorption (Figs. 16/17) of welds with different kinds of electrode.

Nevertheless, the data given may suffice to show that, to-day, welding has become an economical and reliable method of construction which can no longer be divorced from the technology of modern machine structure and which can be relied on, confidently, when supported by unremitting and conscientious control tests.

(MS 563) *H. Zschokke. (Mo.)*

THE PRIMARY-CURRENT THERMAL RELAY, TYPE HT.

Decimal index 621.316.925.44.

I. INTRODUCTION.

WHEN should a relay cause the circuit breaker which it protects to trip? There are two contradictory answers to this question, which, at the same time, clearly subdivide the field of application of a relay. All cases of trouble which open an undesirable track for the current should be cut out *as soon as possible;* among these are short circuits, earthings, faults in the insulation of lines and of machines. Machines and lines which are unaffected by a disturbance should be cut out *as late as is allowable* when the system on which they work demands of the said machines heavy overloading capacities. Here, the temperature rise of the part of the plant affected is the only deciding factor as to when the cut out must take place. The two fields of application thus defined are, therefore:— *short-circuit or fault protection* and *overload protection.*

Apart from the selective-protection system, definite time limit over-current relays are, chiefly, utilized as a protection against short circuits, these relays have already been described here.[1] Protective measures against overloading, on the contrary, are still lacking in uniformity. In the case of big machines, temperature-measuring devices are utilized to actuate signals. Motors for low voltages are, usually, protected by switchboxes equipped with thermal relays. In high-voltage plants, the overload protection is usually entrusted to the short-circuit protective relay although the latter — even in the case of an inverse-time limit over-current relay — is not equal to the task, for two reasons:— firstly, the preliminary loading to which the machines have been subjected is not taken into consideration; the tripping times are the same whether the trip follows a full-load regime or a no-load regime. Secondly, the time lag is much too short and not adapted to the only decisive factor, namely:— the *temperature rise of the object protected.* The results are, either, much too early tripping, or loss in protective value in the range of overloading, as will be shown later.

II. OBJECT FULFILLED BY THE RELAY AND ITS PROPERTIES.

The new overload relay, thermal relay Type HT, has been designed to satisfy these requirements and does so, thanks to its properties set out, herewith.

(a) The main current flows continuously through the relay and heats it up, just as it heats the object which the relay protects. The relay indicates its temperature on a scale and it trips when the maximum allowable temperature set to has been attained. If it is found possible to design the relay so that, as the strength of the current varies, it shows the same temperature, at any moment, as that of the object it protects, then it can be said to become a *thermal image* of the object protected and acts like a contact thermometer lodged in the latter. To attain this object, there are two main conditions to be fulfilled:— firstly, the final temperature attained by the relay and the object protected, under constant current load, must be the same or proportional to one another. This is attained by a suitable choice of the rated current of the relay and by making the effect of the current on the relay an adjustable factor; secondly, the rapidity of the rise and fall of temperature in relay and object protected must be the same. The temperature curve in function of time of any body heated by a constant amount of power is an exponential function. As the final temperature is, in theory, only reached after an infinite space of time, it is usual to take as magnitude that time required by the body in order to reach 63 % of the ultimate temperature and to term this magnitude the thermal time constant τ. If, now, care is taken that the time constant of the relay be equal to that of the object protected, then condition 2 has been fulfilled. The time constant of the relay is, therefore, made adjustable in three steps of 15, 30 and 45 minutes, by putting on heat carriers of various capacities. For the purpose of comparison, Table I gives the time constants of different parts of a plant.

TABLE I.

Time constants of different parts of a plant.

		Time constants
Motors: 0·3 up to 8000 kW	about	25 to 50 min
Generators: 5000 up to 30,000 kW		
Slow-speed machines	„	25 to 60 min
High-speed (turbo) machines	„	25 to 45 min
Transformers: 100 up to 10,000 kW		
Average oil temperature with cooling by air	„	2·5 to 3 h
Average oil temperature with cooling by water	„	1 h
Copper in contact with oil	„	5 to 7 min

Cables:— Armoured cables in channels. Time constants in minutes:—

Section, mm²	6 kV	10 kV
16	32	47
25	36	51
35	40	57
50	46	64
70	52	72
95	60	80
120	67	87

[1] The Brown Boveri Review, year 1935, June No., page 119 and December No., page 228.

Now, how does the similarity or divergence of time constants of relays and objects protected work out in practice? The case of *identical time constants* has already been explained in the preceding paragraphs:— it is the aim striven after:— the creation of the thermal image. *Lower time constants* of the relay cause the relay to lead on the object protected when current changes occur, both in increasing and decreasing sense. Thus, under overloads, the relay will act before the temperature-rise limit of the object protected has been attained. The smaller time constant of the relay, thus, always acts in the sense of increased safety. Often, a smaller time constant of the relay will be chosen intentionally, or the relay will be used with advantage in plants in which its biggest possible time constant is still considerably smaller than the time constant of the object protected. Contrary conditions are brought about by using *bigger time constants* for the relay as compared to those of the objects protected. Under these conditions, overloads might bring about excessive heating of the part of the plant protected. *Therefore, the time constant of the relay should be chosen equal to, or smaller than, the time constant of the object protected.*

In this respect, it should be added that the actual heating curves of the different electric parts of the plant differ from the thermal exponential curve, because, when a conductor heats up quickly, the temperature thereof leads the more markedly on the temperature of its surroundings, the quicker the said heating up takes place. The thermal relay takes faithful account of this phenomen.

(b) It is usual and in conformity with regulations to indicate the admissible heating up in terms of temperature rise, that is to say to leave the surrounding temperature out of consideration. For this reason, the relay is equipped with a compensation of surrounding temperature and, thus, acts in dependance of the *temperature rise.* In special cases, this compensating feature can be eliminated and then the relay acts on the *real temperature* of the object protected, if the relay is in the same room as the object in question.

(c) The relay is equipped with limit-current instantaneous tripping. It works, according to setting, either in conformity with its thermal characteristic alone, or else it acts instantaneously when an adjustable multiple of the rated current has been exceeded, whatever the temperature may be.

III. DESIGN.

The current flows through coil a (Fig. 1) which magnetizes an iron circuit b. This circuit and the weights b serve as heat carriers and contain the heating device and temperature-measurement organ. Scale c shows the temperature rise of the relay, between 0 and 120° C. The desired tripping temperature rise is set by means of scale d, this between 20 and 120° C. *The relay is so designed that when fed*

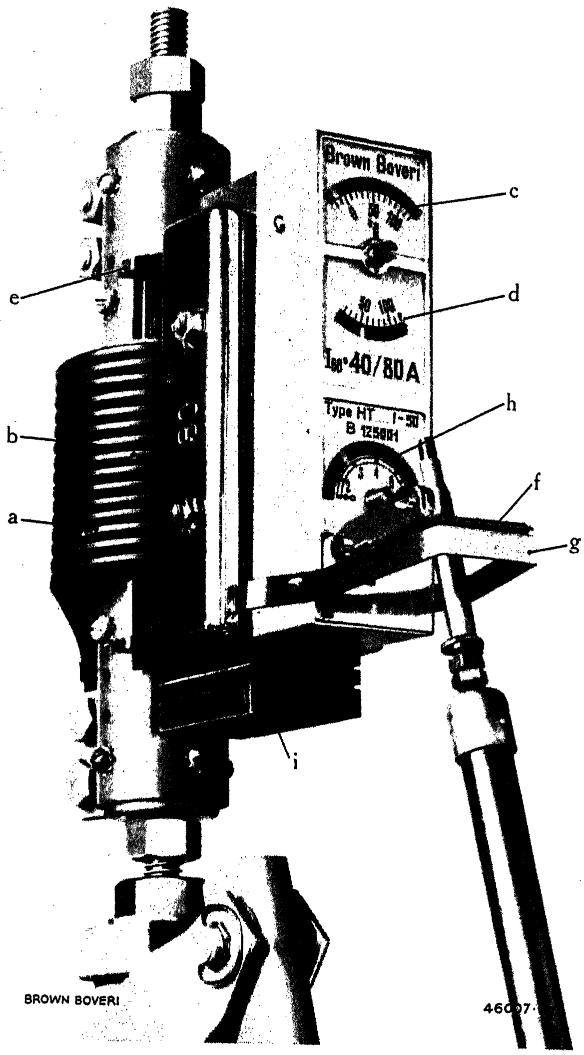


Fig. 1. — Primary-current thermal relay, Type HT.

a. Current coil.
b. Heat carrier.
c. Temperature-rise indicator.
d. Setting scale of the tripping temperature rise.
e. Keys for adjusting current and temperature respectively.
f. Tripping lever.
g. Tripping signal.
h. Instantaneous limit-current tripping.
i. Compensating device for surrounding temperature.

with the standard rated current it indicates 60° C temperature rise. By adjusting a key piece e, which is equipped with calibrating marks from 1 to 2, the same temperature rise of 60° C can be chosen, in a range of once to twice the rated current, or, when supplied with the rated current, the indicating temperature can be modified in the range of 60 to 15° C. This allows of great adaptability to the temperature of the object protected. i is the device for compensating the temperature of the surroundings. The relay trips when the temperature indicator c attains the figure set by the adjusting indicator d, this by releasing the catch of tripping lever f. After tripping has taken place, the tripping lever is again loaded, either by an auxiliary device on the breaker which loads the relay through the agency of the tripping rod or else the tripping lever — eliminat-

ing the additional device — can be reloaded by means of the service rod. An indicator g shows that the breaker has been tripped. Reclosing is possible in about 30 seconds after the tripping or immediately, if the tripping temperature is set, momentarily, somewhat higher. Of course, instead of carrying out a tripping operation, the relay can be made to simply carry out signals. In this case the tripping lever works on a contact instead of on the breaker catch. The limit-current instantaneous tripping is taken care of by scale h which can be set between two and ten times the value of the rated current which has been adjusted to by key e. Limit-current tripping is blocked in the ~ position.

The tripping times of the thermal relay from cold condition can be obtained from the curves of Figs. 3 to 5. The different curves are valid for the settings chosen for the tripping temperature. Curves b in Figs. 3 to 5 give the temperature rises indicated by the relay

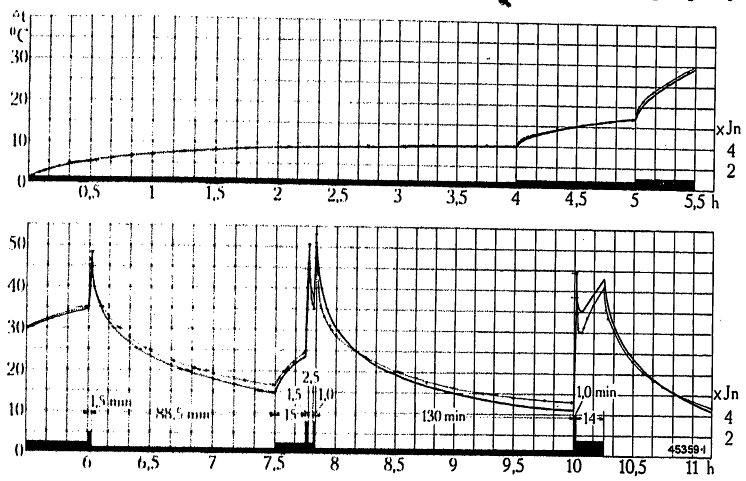


Fig. 2. Primary-current thermal relay, Type HT, as thermal image of an 8-kV cable, 3 × 16 mm².

——— Temperature of copper of the cable, as measured by means of thermo-elements.
x x Points read off on the temperature-indicating device of the thermal relay.

in function of the position of the adjusting key, when the relay is supplied with the rated current. The height of the thermal relay is the same as that of primary-current relays Types HB 4 and HK4, the same applies to the arrangement, to the blow and travel of the tripping lever. The big resistance to short circuits is a feature of great importance, it attains about 1000 times the standard current rating. The temperature-measuring organ is practically indestructable. All mechanic parts are rustless. Table II gives a summary of the interesting technical data of the thermal relay.

It is intended to build the thermal relay as a secondary relay, as well.

IV. FIELD OF UTILIZATION.

(a) *Protection of machines and cables.*

Generators, high-voltage motors and cables are the chief among the objects to be protected by the thermal relay. Their time constants are within the range of the relay and the relay can be designed to form the thermal image of the said objects. Thus, in the case of generators, the thermal relay gives complete protection against overloads, along with great security against undesired tripping due to trouble on the distribution system. Hunting phenomena, according to its influence on the heating of the machine, come within the scope of protection afforded by this relay. In the case of high-voltage motors, the relay permits of current peaks at starting without danger of breaker trippings when occasional excesses in the duration and in the magnitude of the starting currents occur, this in so far as the allowable temperature rise of the motor and starter respectively are not exceeded. The same thing applies to the protection of cables.

A test carried out, the measured values of which are reproduced in Fig. 2, gives information on the exactitude of the thermal image which the relay forms of whatever object is being protected, when the relay is properly suited to the object in question. A cable for 8 kV, 3 × 16 mm² with a time constant $\tau = 48$ min was equipped with an HT relay with a time constant $\tau = 45$ min. The temperature rise of the copper of the cable was measured by means of thermo-elements and is shown in Fig. 2 as a thick line. The crosses are points at which readings of the temperature indications of the relay were made. The load current at the different periods is drawn in under the curves. The test lasted for 11 hours and includes, in the time range 0 to 6 hours, the behaviour of the relay in a current range up to full-load current. As will be seen, the concidence is, practically perfect; above all, the test shows the suitability of the relay as a temperature-indicating instrument. The time range from the 6th to the 11th hour shows the behaviour of the relay under ordinary service overloading of 2 to 4 times the rated current. At the moment of the sudden application of the overloads, the temperatures of cable and relay increase in what is practical coincidence with each other, the relay exceeding the temperature peak of the cable by about 3 to 5° C. This forms a quality of safety which has been imparted intentionally to the characteristic of the relay. During the long cooling down periods the maximum divergence of temperature is about 3° C. This second time section shows the remarkable exactitude of the thermal image in the range of the highest service overloads.

However, as compared to the thermal relay, transformers have, generally, got higher time constants. Nevertheless, the HT relay also imparts to transformers a freedom, up till now unknown, in the range of service currents allowable, with absolute safety as regards excessive heating. It must be remembered that the current setting and temperature adjustment of the relay and not the time constant are the factors determining the highest continuous service current allowable, which, if exceeded, brings about the

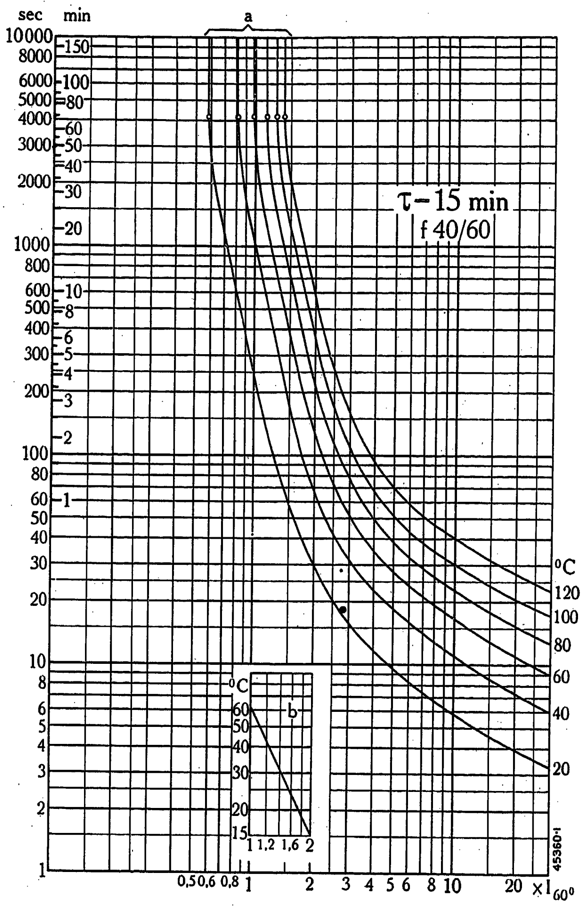


Fig. 3. — **Primary-current thermal relay, Type HT.**

(a) Tripping time in function of excess current, for different settings of the tripping temperature rise. $\tau = 15$ min.

(b) Indicated temperature rise, when relay is supplied with I_n in function of adjustment of the key.

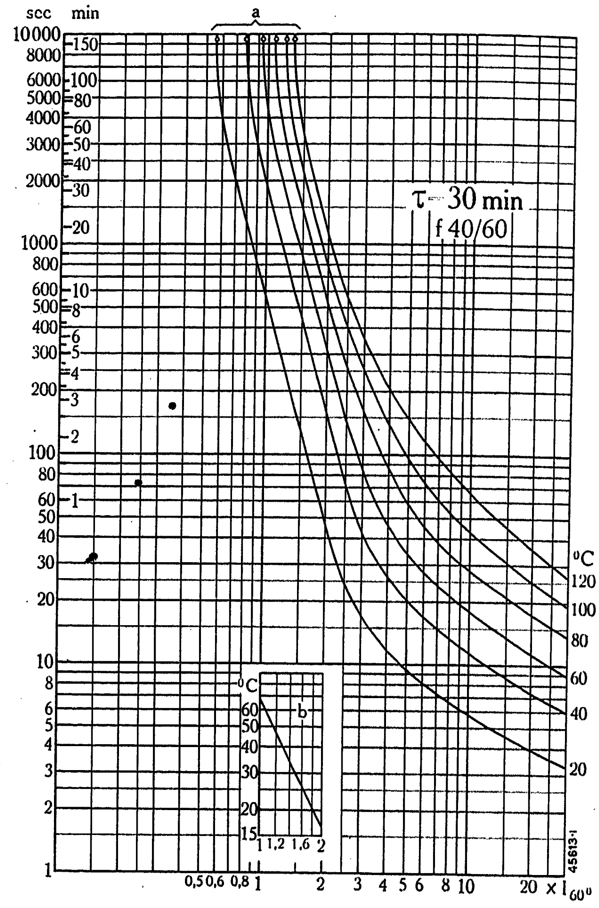


Fig. 4. — **Primary-current thermal relay, Type HT.**

(a) Tripping time in function of excess current, for different settings of the tripping temperature rise. $\tau = 30$ min.

(b) Indicated temperature rise when relay is supplied with I_n, in function of adjustment of the key.

tripping of the breaker. The prematureness of the cutting out under overload as a result of the smaller time constant of the relay is all the less, the higher the service temperature of the transformer before the overload is imposed.

These considerations are also valid for all other fields of application in which the relay has a smaller time constant than the object protected.

(b) *Complementary protection to the short-circuit protection of lines.*

In simple networks, primary relays, suitably graded as to time lag, are chiefly used as a protection against short circuits. In order to prevent the relay being stressed too severely when the maximum short-circuit current flows, the rated current I_n of the relay must not be chosen lower than:—

$$I_n \min = \frac{\text{max. short-circuit current at location of relay (amp.)}}{\text{short-circuit resistance of relay } (\times I_n)}$$

In the case of big systems, especially, the lowest-admissible rated current of the relay and tripping current, respectively, is often considerably higher than the standard-rated current for which, for example, the section of the cable is calculated. This, however, means that the cable is unprotected in the current range between maximum allowable service current of the cable and tripping current of the relay. Here, the thermal relay is the remedy, inserted, for example, on the third phase, while the short-circuit protection relays (as time-graduated short-circuit protection) are on the two other phases. The thermal relay takes over the protection of the cable against too high temperatures. On account of its high short-circuit strength, it stands up to the highest short-circuit currents which may occur. It may also happen that a cable system is equipped with distance-relay protection and that the current transformers of the bushing type are designed for relatively high primary current ratings in order to get sufficient power from them. Cable lengths of small section also show a range of unprotected current, in this case, between the highest cable current admissible and the tripping current of the selective protection. This weakness can also be remedied by using the thermal relay.

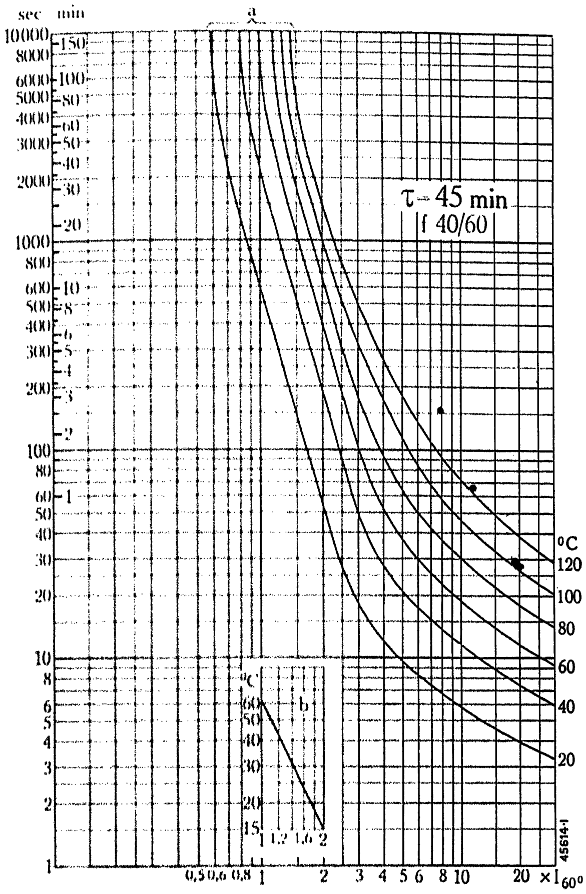


Fig. 5. Primary-current thermal relay, Type HT.

(a) Tripping time in function of excess current, for different settings of the tripping temperature rise. τ = 45 min.

(b) Indicated temperature rise when relay is supplied with I_n, in function of adjustment of the key.

(c) *Combined short-circuit and overload protection.*

Current consumers supplied from power station buses and from substations of the distribution system get the shortest time-lag setting of all the relays on the system, when graded short-circuit protection by means of definite time limit over-current relays is applied. These customers are the extreme branches of the system and if their plants are subject to a short circuit they must not be the cause of sections placed closer to the source of supply being cut out, as well. The setting of the time lag of the over-current relays of these power consumers, who also require time grading for the relays of breakers in their own plants, is often a very difficult problem and seldom leads to solutions satisfactory both to power supplier and power consumer. The use of the thermal relay on the branch line in question removes the difficulties. The limit-current tripping of the thermal relay is so set that an instantaneous tripping takes place when the tripping current of the short-circuit protection relay on the system is attained. As this value is, usually, far above the rated current of the consumer, there is only an instantaneous cut out if a real short circuit takes place, that is when the said tripping is unavoidable. On the other hand, the strongly inverse time characteristic of the thermal relay allows the necessary time for the selective grading of the definit-time limit over-current relays in the consumer's plant for all ordinary cases of overloading in the plant which are much below the instantaneous tripping setting and, further, permits of limiting the thermal mean value of the power consumed.

In cases when power consumers taking little power are to be protected and when the short-circuit capacity of the system is high, the HT relay allows of great freedom in the range of the consumer current and, owing to its great short-circuit strength, it is the most suitable organ for instantaneous tripping when a short circuit does occur.

The examples given do not exhaust the field of application of the thermal relay, but they show that the new apparatus fulfills a real need. Used along with definite-time limit over-current relays, the HT

TABLE II.

Primary-current thermal relay, Type HT.

Technical data	f = 50 Hz
Indication of temperature rise	0—120° C
Setting range of temperature rise tripping	20—120° C
Influence of the surrounding temperature	compensated
Current for 60° C temperature rise; to be set by the position of the keys (The key setting gives at what multiple of the rated current 60° C temperature rise will be indicated on the relay.)	1—2 I_n
Admissible continuous temperature rise indicated	100° C
Thermal time constant chosen as desired (Carried out by putting on the corresponding heat carriers with indications 15, 30, 45.)	15, 30, 45 min
Tripping time in function of the current for various settings of the tripping temperature:	
for τ = 15 min	see Fig. 2
„ τ = 30 min	„ „ 3
„ τ = 45 min	„ „ 4
Limit-current instantaneous tripping, range of adjustment	2—10×$I_{60°}$
Margin of value adjusted to in %	± 10%
Short-circuit strength, dynamic (peak value)	abt. 1000 I_n max. 100,000 A
Reclosing after tripping by device on breaker or by hand with service rod	
Interval before reclosing after a thermal tripping	abt. 30 s
Force of blow and travel of the tripping lever	1 kg×2 cm
Indication of a tripping operation effected	signal

relays gives an entire short-circuit and overload protection of electric plants, from the generator through the distribution system to the consumer's machine.

Definite-time limit over-current relays for short-circuit protection allow of sharply defined stepping and short tripping times, when short-circuit trouble occurs.

Inverse-time limit relays if they have the thermal characteristics of the HT relay, used as over-load protection, prevent superfluous trippings of breakers, allow a big range of service overloading and protect the plant parts against unallowable overheating.

(MS 574) *J. Stoecklin. (Mo.)*

NOTES.

Low-voltage electric-boiler plant belonging to the Latteria Luganese, Massagno (Switzerland).

Decimal index 621.181.146.

THE electric-boiler plant of the Latteria Luganese, Massagno, is dimensioned for a power input of 100 kW at 380 V and 6 kg/cm² abs pressure.

This is an electric-boiler of the standard Brown Boveri low-voltage design with electrodes secured to the boiler cover, power regulation being effected by varying the level of the water, that is by the amount of immersion of the fixed electrodes.

The boiler, with the feed-water pump set and the combined regulating devices, forms a unit allowing the plant to be operated quite automatically. The feed-water tank is located beside the boiler and has a float regulating

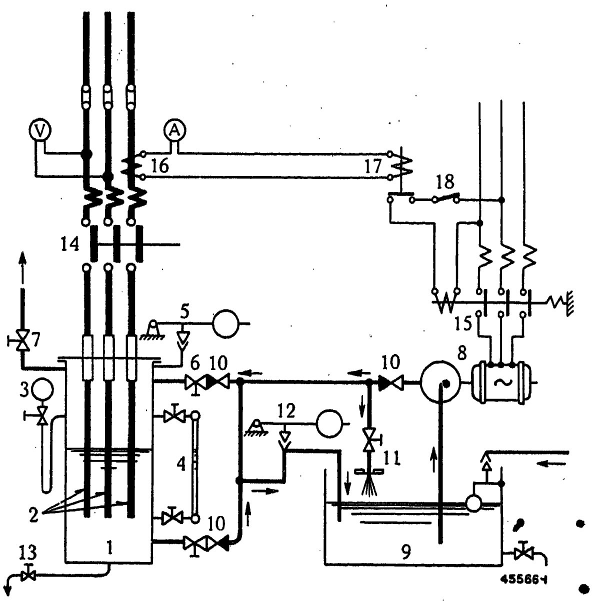


Fig. 1. — Low-voltage electric-boiler for steam production, of Brown Boveri design. Regulating diagram.

1. Electric-boiler.
2. Electrodes.
3. Manometer.
4. Water level.
5. Safety valve.
6. Feed-water valve.
7. Main steam valve.
8. Feed-water pump set.
9. Feed-water tank.
10. Check valve.
11. Diaphragm.
12. Relief valve.
13. Blow-down valve.
14. Main circuit breaker.
15. Motor contactor.
16. Current transformer.
17. Relay.
18. Hand switch.

device which allows that quantity of water to flow in, continuously, which is required to keep the level in the tank constant.

The automatic regulation of the boiler is shown in Fig. 1. The feed-water pump 8 working to constant supply volume draws water from the feed-water tank and drives it into the boiler over the feed-water valve 6. The amount of water flowing into the boiler is determined by whatever pressure there is in the boiler itself. The amount of feed-water which does not flow to the boiler, on account of the counter pressure being too high, flows over diaphragm 11 back to the feed-water tank. If the pressure in the boiler drops owing to increasing steam consumption, nearly all the feed water will flow

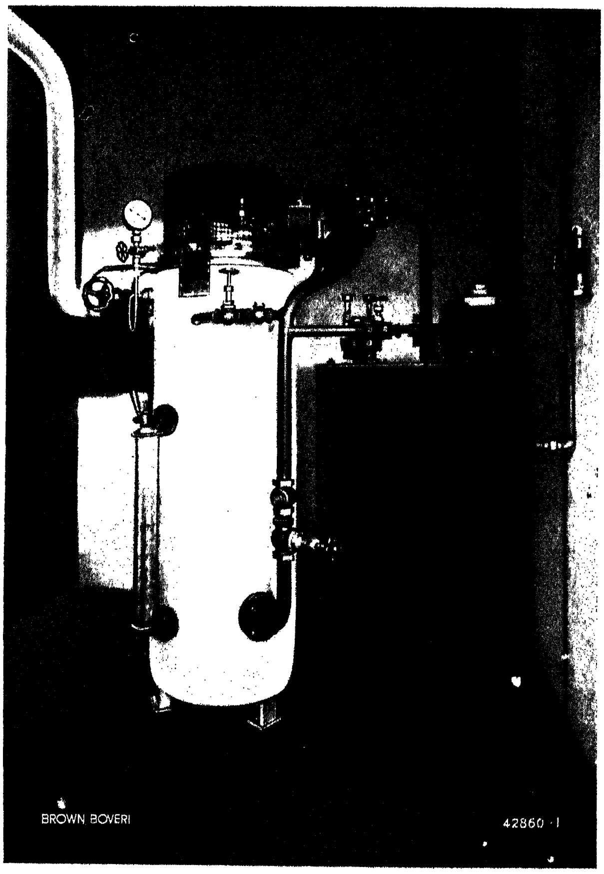


Fig. 2. — Latteria Luganese, Massagno (Switzerland)
Electric boiler for steam production, input 100 kW, 380 V, 60 kg/cm² gauge.

to the boiler, in which the water level rises, at once, and a bigger load is attained corresponding to the bigger consumption of steam.

When the steam consumption goes down, the level of the water must be lowered immediately and, to this end, the supply of water to the boiler cut off. This is carried out automatically by the increase of the pressure in the boiler so that the whole quantity of feed water from the pump flows back over diaphragm 11 to the feed-water tank. Further, it is necessary to evacuate a part of the water already in the boiler. This is also an automatic operation brought about by the higher pressure generated in the boiler. The boiler is evacuated through the relief valve 12 which opens as soon as the pressure in the boiler reaches a certain limit value. This limit

pressure is generally set at about 1/2 kg/cm^2 below the highest service pressure admissible.

The switchgear of the electric-boiler plant is composed of a switchbox with oil circuit breaker, three built-on over-current relays as well as one ammeter and one voltmeter.

In order to prevent the water level in the boiler becoming too high, as a result of a sudden increase in steam consumption and the pressure drop resulting therefrom, which would mean that the boiler would consume too much electric power, there is a current transformer which supplies a current relay and this limits the supply of electric power to the boiler. This relay causes the motor driving the feed-water pump to be cut out when the electric power supplied to the boiler attains about 120% of the rated figure. The motor only starts up again automatically when the power supplied to the boiler has gone down to about 90% of the rated figure.

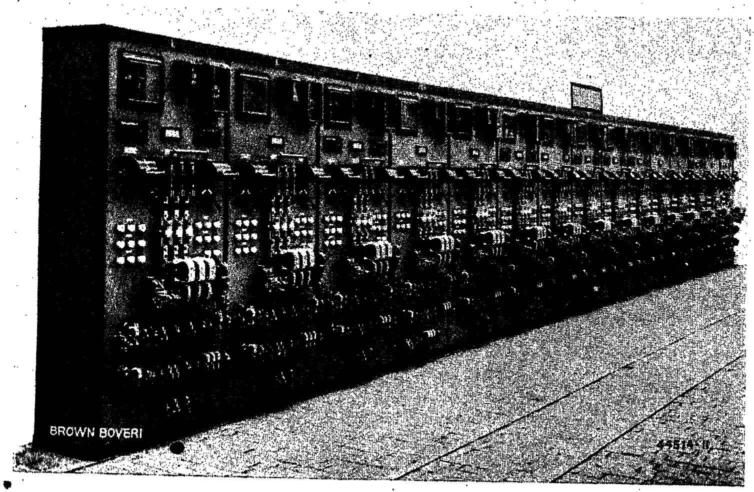


Fig. 1. — Switchboard for the drive of the rotary printing press of the "Paris-Soir".

Finally, it should be noted that the electric-boiler plant described is supplied with raw water exclusively; it very rarely happens in dairy plants that condensate is available. Further, it is worthy of note that this service is subjected to very heavy load fluctuations and, thus, causes the automatic pressure and feed-water regulation of the boiler to work under severe conditions. The Brown Boveri low-voltage boiler stands up to severe service conditions, like these, perfectly well and experience gathered in this and other plants confirm the absolute service safety and reliability of this new type of boiler.

(MS 567) *E. Soldati. (Mo.)*

The drive of the rotary printing press of the newspaper "Paris-Soir".

Decimal index 621.34:651.31 (44).

Up till lately, the well-known French newspapers "Paris-Soir" and "Paris-Midi" were printed in their own printing works in the rue du Louvre and in different printing establishments hired for the purpose. On account of continuously increasing circulation and the necessity of making the printing independent of outside printing works, the building of a further printing works for the newspapers in question was begun in the rue des Petites-Ecuries, in the year 1936. This printing works, the first development stage of which was to comprise a 12-reel rotary press and a four-reel rotary press, was put to work at the end of August 1937, with five units of the first press mentioned. The distribution of space in the printing plant was so made that, later, two further similar machines could be added.

For both rotary presses, electric driving equipment with three-phase shunt commutator motors and entirely automatic push-button control by Brown Boveri was installed.

The 12-reel rotary press, which is 34 m long and 7 m high, is composed of 12 printing units for black printing, 3 double folding machines and 3 further colour-printing units. This machine has a maximum speed of 25,000 cylinder rotations per hour, at which speed each double folding machine delivers 50,000 finished-folded newspapers. The 12 printing units can be so combined with the three folding machines that a maximum of 50,000 16-page or 25,000 32-page newspapers, per folding machine and per hour, can be printed. The rotary machine is, then, subdivided into three sets with, each, 3 and 4 printing units respectively, with or without colour-printing unit. The machine can, also, be subdivided into two sets, each having a folding machine, and with the middle folding and corresponding colour-printing unit cut out. In this case, each set comprises six printing units and a folding machine, with or without colour-printing unit. In this combination, the printing capacity per folding machine and per hour has a maximum of 50,000 copies of 24 pages each.

Each printing unit for black print and each of the three double folding machines, with which the colour-printing units can be coupled, has its own drive. There are, thus, 15 driving sets located in a line alongside the machine.

A driving set is composed of a three-phase shunt commutator motor, as main motor, with an output of 50 H.P. and a range of speed variation of 1 to 5, and a 4 H.P. slip-ring motor with reduction gear and overhauling clutch as auxiliary drive. The longitudinal shaft of the machine, which is subdivided, by coupling, in accordance with the possibilities of combination of the printing press, is driven by the motor through tooth chains.

The machine is exclusively governed by push buttons, in the ordinary way, as this is the only possible method when its size is taken into consideration. To this end, there is a push-button station per folding machine, with five push-buttons, for "Inching", "Introducing", "Faster", "Slower" and "Stop", and per printing unit two push-button stations, each with three push-buttons for "Inching", "Introducing" and "Stop". Further, there are some "Stop" push-buttons located at different points of the machine considered most useful. Each push-button station has got, apart from the push-buttons, a safety rotary switch to block the machine and two signal lamps. The latter show whether the machine is blocked or ready for service. The speed of the machine can only be adjusted at the folding machines, at which points the printing and folding operation can be supervised.

The controls of the different driving sets are combined by means of drum switches in the switchboard, according to the combinations which it is possible to carry out in the printing press. The switchboard is about 14 m long and carries all the switchgear apparatus, instruments and fuses. To allow of good supervision and accessibility, it is of open design and is placed in a special chamber. Fig 1 shows this switchboard.

As a special feature of this Brown Boveri rotary printing press drive, mention must be made of the automatic regulation to equal load of the three-phase shunt commutator motors which are coupled through the driving shaft, a system of regulation already described in The Brown Boveri Review of October 1937. This regulating device is automatically switched-in in the proper connection when the governing of the various drives are combined by the drum switch according to the desired grouping of the printing units.

Apart from the driving sets proper, there are further auxiliary drives for the reel stands, which are also

governed by push-buttons; there is also an automatic paper-draw regulating gear on the machine.

No difficulty was encountered in putting the rotary printing press to work, after the control relays for the regulating system described had been set according to the loads on the motors. Drives, push-button control and regulation to proper load distribution among the motors all worked perfectly and to the satisfaction of the clients. There is only some few percent difference in the loading of the motors in parallel service.

(MS 578) *A. Auer. (Mo.)*

Three-phase shunt commutator motors of low output.

Decimal index 621.313.362.025.3.

EXCELLENT speed-regulating qualities, simple supervision and low power consumption are the chief features which make the three-phase shunt commutator motor the ideal one for plants where speed variation is wanted and these qualities open up an ever-increasing field of application to this motor. As is known, the speed of these motors can be varied by brush displacement, perfectly smoothly and without losses, over a wide range of speed. This is carried out in the simplest manner possible, by rotating a handwheel or by depressing push-buttons. The motor can be connected straight to the three-phase supply system, there is no need of conversion, as in the case of D. C. drives. Therefore, better efficiencies and a simpler layout are attained.

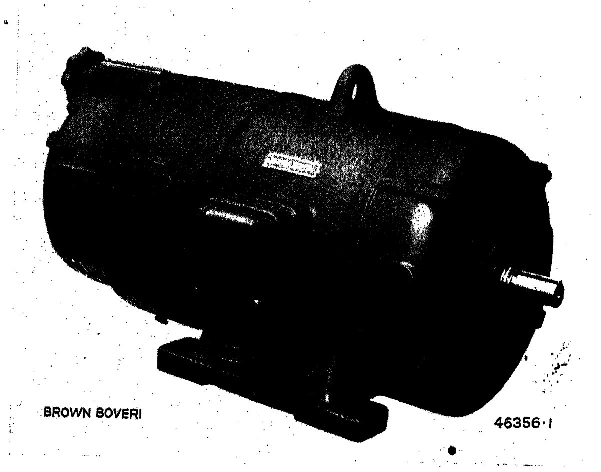


Fig. 1. — Drip-water proof three-phase shunt commutator motor, Type PN 64, 3·3 kW, 2000—670 r. p. m., 380 V, 50 Hz.

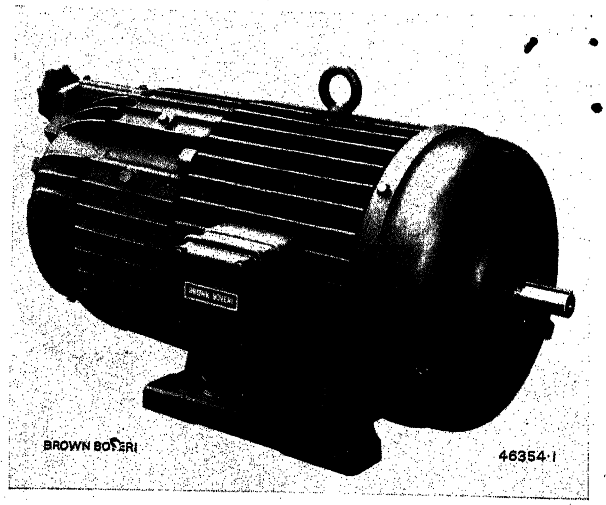


Fig. 2. — Totally-enclosed externally-cooled three-phase shunt commutator motor, Type PNU 64, 1·85 kW, 2000—670 r. p. m., 380 V, 50 Hz.

Up till now, the big advantages of these variable-spped drives have been made little use of in the range of low outputs, that is for outputs below about 4 kW. When wide ranges of regulation are called for, D. C. motors for speed regulation have been used for the drive of industrial machines of low outputs. Three-phase slip-ring motors are also used although their series caracteristic, when regulated by resistances inserted in the rotor, is against them. Innumerable small machines in a multitude of trades and industries are equipped with some system allowing of mechanical speed regulation. These systems generally give only mitigated satisfaction, on account of considerable wear or the coarse stepping of the speed variations, or other drawbacks. To meet the requirements of machines of this kind, Brown Boveri has developed small three-phase shunt commutator motors and, thus, met the call for a motor the speed of which can be regulated purely electrically and in a simple manner. Among promising fields of application for these motors, mention may be made of warping machines in the weaving industry, dyeing machines of all kinds, small printing presses, transverse cutters, rubber machines, certain classes of machine tools, coal screw extractors in cement mills, etc. The motor is built to the four-pole type and, usually, with a speed range of 1 to 3 or 1 to 5, in two designs:— drip-water proof and totally-enclosed with external fan cooling. At a frequency of 50 Hz the drip-water proof motor type (Fig. 1) delivers 3·3 kW at the highest rated speed of 2000 r. p. m. and this in the design for a speed range of 1 to 3, while the totally-enclosed type (Fig. 2), delivers 1·85 kW. Both types can be built for lower outputs, for a considerably wider range of speed regulation. In the case of the drip-water proof motor, the surrounding air is utilized as cooling agent and drawn in axially through the motor. The interior of the totally-enclosed motor, with external-fan cooling, however, is entirely cut off from external influences. Its windings have special insulation and the housing is given an external and internal coating of rust-proof paint. The cooling air is blown over the housing and bearing shields, which have cooling ribs, by a fan on the driving side. This design is especially recommendable for motors in chemical and dye works, and the like. A handwheel is, usually, employed for the displacement of the brushes. A scale with indicator, placed on the top and visible in the illustration, gives the position of the brushes. When necessary, a mechanical remote-control gear with chain or bevel gear drive can be put in, instead of the handwheel, or else an electric remote control with a small servo-motor drive, similar to the equipment put on bigger motors. In order to allow of straight coupling to slow-running machine shafts, the motor can be combined with a reduction gear. Finally, motors can be delivered without feet and with a flanged bearing shield to allow of mounting the said motor horizontally or vertically.

Thus the mainfold demands of modern practice can be satisfied. These new possibilities as regards variable speed regulation should meet with general interest and be utilized, not only for the drive of the machines already mentioned, but in many other branches of industry.

(MS 580) *H. Wildhaber. (Mo.)*

Built-in motors.

Decimal index 621.313.13.

THE so-termed "standard motor" is built to so many designs, to-day, that nearly all demands concerning the combination of the motor and the machine it drives can be satisfactorily met. It is to the interest of the machine-tool manufacturers to take advantage of the many variations of motor design available when designing their own machinery. When it is simply a case of bolting a suitable motor to the machine, the task is considerably simplified if the machine design allows of this without alterations